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# HAM RADIO

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**Digital Voice Storage  
in the Ham Shack**



**Skywave Communications**

# Introducing Wide Band Receivers...

ICOM has broken the barriers with its new line of wideband receivers built to go the distance. Introducing the IC-R1 handheld receiver, the IC-R72 HF receiver and the IC-R100 multi-purpose receiver.

**IC-R1.** The smallest wideband handheld available today, the IC-R1 continuously covers 100kHz—1300 MHz with AM, FM and Wide-FM modes. This tiny receiver measures just 1.9"W x 4.0"H x 1.4"D.

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The IC-R1, IC-R72 and IC-R100 join ICOM's current line of professional quality receivers... the IC-R71A, IC-R7000 and IC-R9000. ICOM... expanding the horizons to bring you better technology, today. See the complete line of quality ICOM receivers at your local authorized ICOM dealer.

*For a brochure on this or any other ICOM product, call our Toll-Free Literature Request Hotline 1-800-999-9877.*

**ICOM**  
First in Communications

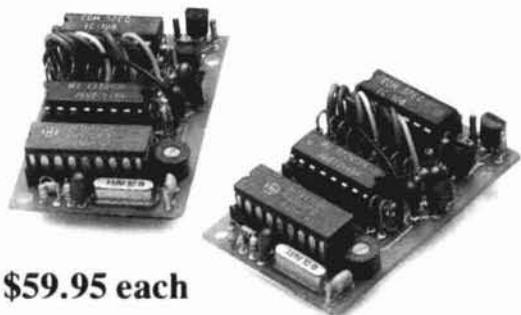
## ...That Go The Distance.



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We just struck gold with a miniature, high quality and very reliable DTMF decoder at a rock bottom price of \$59.95. Our DTD-1 will decode 5040, 4 digit codes with the security of wrong digit reset. It contains a crystal controlled, single chip DTMF decoder that works great in bad signal to noise environments and provides latched and momentary outputs. Why carry that heavy gear when its size is only 1.25 x 2.0 x .4 inches and it comes with our etched in stone, legendary, one year warranty.

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## Affordable DX-ing!

### TS-140S/680S HF transceiver with general coverage receiver.

Compact, easy-to-use, full of operating enhancements, and feature packed. These words describe the new TS-140S HF transceiver. Setting the pace once again, Kenwood introduces new innovations in the world of "look-alike" transceivers!

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- All modes built-in. LSB, USB, CW, FM and AM.
- Superior receiver dynamic range Kenwood DynaMix™ high sensitivity direct mixing system ensures true 102 dB receiver dynamic range.
- New Feature! Programmable band marker. Useful for staying within the limits of your ham license. For contesters, program in the suggested frequencies to prevent QRM to non-participants.

- Famous Kenwood interference reducing circuits. IF shift, dual noise blankers, RIT, RF attenuator, selectable AGC, and FM squelch.
- M. CH/VFO CH sub-dial. 10 kHz step tuning for quick QSX at VFO mode, and UP/DOWN memory channel for easy operation.
- 31 memory channels. Store frequency, mode and CW wide/narrow selection. Split frequencies may be stored in 10 channels for repeater operation.

- Selectable full (QSK) or semi break-in CW.
- RF power output control.
- AMTOR/PACKET compatible!
- Built-in VOX circuit.
- MC-43S UP/DOWN mic. included.

#### Optional Accessories:

- AT-130 compact antenna tuner
- AT-250 automatic antenna tuner
- HS-5/HS-6 headphones
- IF-232C/IF-10C computer interface
- MA-5/VP-1 HF mobile antenna (5 bands)
- MB-430 mobile bracket
- MC-43S extra UP/DOWN hand mic.
- MC-55 (8-pin) goose neck mobile mic.
- MC-60A/MC-80/MC-85 disk mics.
- PG-2S extra DC cable
- PS-430 power supply
- SP-41/SP-50B mobile speakers
- SP-430 external speaker
- SW-2100 SWR/power meter
- TL-922A 2 kW PEP linear amplifier (not for CW QSK)
- TU-8 CTCSS tone unit
- YG-455C-1 500 Hz deluxe CW filter
- YK-455C-1 New 500 Hz CW filter.



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### TS-680S All-mode multi-bander

- 6m (50-54 MHz) 10 W output plus all HF Amateur bands (100 W output).
- Extended 6m receiver frequency range 45 MHz to 60 MHz. Specs. guaranteed from 50 to 54 MHz.
- Same functions of the TS-140S except optional VOX (VOX-4 required for VOX operation).
- Pre-amplifier for 6 and 10 meter band.

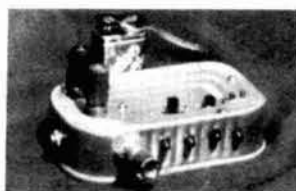
Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications, features, and prices are subject to change without notice or obligation.



# HAM RADIO



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# Backscatter



## Amateur Radio growth?

I understand that the running number of radio Amateurs remains nearly constant. That is to say, the population is not increasing. To combat this, a no-code VHF license has been proposed that presumably will remove a large stumbling block for the would-be ham. The result will be more radio Amateurs in the long run, making the Amateur Radio service more viable and healthy. Right?

Perhaps. However, we may be barking up the wrong tree. I suggest you take an hour or so and listen to the spectrum between 26 and 29 MHz. CB radio, as it was known, has disappeared and a new form of "hobby" radio has grown up in its place. The full 3-MHz range is chock full of SSB stations going about their business in a "ham-like" attitude. *Seemingly* absent are the loud-mouthed ignoramuses who made CB radio a shambles a few years ago. In their place are thousands of operators, behaving themselves, and having fun! There's plenty of DX in this range, too. I counted 14 countries in about 30 minutes listening time. Not much talk about equipment, but a lot of chatter about friendships and local color. It sounded very interesting. Too bad these thousands of operators are not hams!

But why should they be hams? What's the advantage? They can converse and enjoy themselves with no danger from the FCC. They exchange QSL cards and other pleasantries — and they have 3 MHz of space to do it! More frequencies than any HF ham band. The future radio hams are already on the air, and I don't see any chance of them becoming licensed Amateurs because there's little in it for them! They don't need Amateur Radio as we know it. A modified ham transceiver and a store-bought beam puts the operator on the air, ready to work DX and make new friends. To add insult to injury, I recently received a QSL from an English Amateur. On the card were his call letters and also his "identifier" for CB radio. He had the best of all possible worlds.

As long as the FCC and other licensing bodies allow unlicensed communications to take place in the 27-MHz region, we can't expect Amateur Radio to have much growth. The competition is too strong. And Amateur Radio shouldn't be blamed for either this problem or the lack of growth of the Amateur population! I'm not sure what the solution is, but I do know that a lot of happy people are enjoying the fruits of Amateur Radio the easy way. Can you blame them?

I propose that the ARRL initiate special broadcasts from W1AW in the 27-MHz range. This will, however, require special authorization from the FCC. These daily voice transmissions would include information about Amateur Radio, giving an address to send for more information on how to get a ham license. As time goes on, lessons in Morse code, rules and regulations of the Amateur service, and help with the Amateur exam could be given. A regular on-the-air course in Amateur Radio should be initiated and it could be broadcast right where it's most needed — in the middle of the "hobby" frequency range. I think that 1.5-kW PEP into a multi-element Yagi aimed at the heart of the country would gain a lot of attention among those who are potential radio Amateurs. Just as the Voice of America aims its broadcasts to selected areas of the world, the ARRL could aim its special 27-MHz transmissions at would-be Amateurs. Let's convince them that there is value in getting an Amateur Radio license!

**Bill Orr, W6SAI**

# KENWOOD

## TM-731A/631A 144/450 and 144/220 MHz FM Dual Banders

- Extended receiver range (136.000 – 173.995 MHz) on 2 m; 70 cm coverage is 438.000 – 449.995 MHz; 1-1/4 m coverage is 215 – 229.995 MHz. (Specifications guaranteed on Amateur bands only. Two meter transmit range is 144 – 148 MHz. Modifiable for MARS/CAP. Permits required.)
- Separate frequency display for "main" and "sub-band."
- Versatile scanning functions. Dual scan, and carrier and time operated scan stop.
- 30 memory channels. Stores everything you need to make operating easier. Two channels for "odd splits."
- 50 Watts on 2 m, 35 watts on 70 cm, 25 watts on 1-1/4 m. Approx. 5 watts low power.
- Automatic offset selection.
- Dual antenna ports.
- Automatic Band Change (A.B.C.) Automatically changes between main and sub-band when a signal is present.
- Dual watch function allows VHF and UHF receive simultaneously.
- CTCSS encode/decode selectable from front panel or UP/DWN keys on microphone. (Encode built-in, optional TSU-6 needed for decode.)
- Balance control and separate squelch controls for each band.

- Full duplex operation.
- Dimmer switch.
- 16 key DTMF/control mic. included.
- Frequency (dial) lock.

### Optional Accessories:

- **PG-4H** Extra interface cable for IF-20 (for three to four radios)
- **PG-4J** Extension cable kit for IF-20 DC and audio
- **PS-430** Power supply
- **TSU-6** CTCSS decode unit
- **SWT-1** 2 m antenna tuner
- **SWT-2** 70 cm antenna tuner
- **SP-41** Compact mobile speaker
- **SP-50B** Deluxe mobile speaker
- **PG-2N** DC cable
- **PG-3B** DC line noise filter
- **MC-60A, MC-80, MC-85** Base station mics.
- **MA-700** Dual band 2 m/70 cm mobile antenna (mount not supplied)
- **MB-11** Mobile bracket
- **MC-43S** UP/DWN hand mic.
- **MC-48B** 16-key DTMF hand mic.

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# "Dynamic Duals"



# Comments



## Creative recruitment; Productive leisure time

Dear HR

It is basic construction articles like W3RMD's ("The Five-Band Junkbox Transmitter," *Ham Radio*, December 1989 and "The 80/40-meter Junkbox Rig Revisiting," *Ham Radio*, January 1990) which, in my view, will go far to excite the imaginations of prospective hams and bring them into the fold.

Just as many of us got our feet wet with crystal control and "graduated" to additional frequencies and modes via VFOs and upgrading, so...might beginning with discrete components be the route for today's beginner to license upgrading and state-of-the-art technical skill and knowledge.

We Elmers with well-stocked junkboxes would do well to share our goodies with beginners, young and old, 807s anyone? How about an ARC-5?

Can we target as prospective hams not only those with demonstrated technical skills and interests but also youth and adults who seek a leisure time activity that is not necessarily related to their intended or actual vocations or professions? I think such a strategy would be particularly relevant to older persons, whose numbers in our society are increasing dramatically and for whom Amateur Radio is an opportunity for continued active involvement in life and living that is service oriented. Three eminent hams come to mind in this regard — Senator Barry Goldwater, the late General Curtis LeMay, and King Hussein of Jordan.

Finally, can't we market CW as a second language to prospective hams rather than endure the frustration of defending/rejecting an arguably outmoded if not obsolete communications mode. Those of us who have mastered CW are, after all, bilingual.

**Carlton D. Trotman, W3BRX,  
York Pennsylvania**

## Relaying In Our Roots

Dear HR

What's all the "Bruhaha" about in regard to third-party traffic on the ham bands? As long as it doesn't violate any rule or regulation, national or international, what's the problem?

Looking back at the early beginnings of Amateur Radio, wasn't the "relaying of messages" one of the very many public services that the Amateur Radio operator helped develop, and very efficiently at that? This activity was instrumental in promoting the founding of the ARRL (*American Radio Relay League*).

As for self-policing, no group or society can achieve successful results with that method alone.

We still need a *strong* FCC which needs all the help we can offer; i.e., official observers.

**Alex Hellman, W2OEQ,  
Woodhaven, New York**

## AM alive and well!

Dear HR

This is in reference to "Ham Radio Techniques," by Bill Orr, W6SAI, appearing in the December 1989 issue of *Ham Radio*. We take issue with the statement: "Too bad the days of amplitude modulation are past..." It's a matter of fact that 29.0 to 29.1 MHz is popu-

lated with those using AM. Listen to 14.286 MHz just about anytime and you will find it quite busy. Good 'Ole 160 is still the local favorite for the lower powered AM signal; we use 1890 here in Hawaii. Also, KH6CC and KH6B can be heard often on 7290 kHz using AM. We call your attention to the publication, *The AM Press/Exchange*, published by K4KYV. Also, *Electric Radio*, put out by N6CSW/Ø. No, AM is far from dead! We have heard that it's the fastest growing mode. Many modern solid-state rigs have an AM mode position (wonder why?). Those who, for the first time, heard Amateur AM signals have switched their rigs over to AM and have noticed the "quality mode." Bill Orr, W6SAI, has had kind words towards AM in the past. See "Ham Radio Techniques" in the February 1984 issue of *Ham Radio*.

To conclude, we would like to state that many of us started in Amateur Radio with low powered rigs on 160 meters. Among them are KH6CC, KH6B, and we've heard that W6SAI (under his first call sign) spent a lot of his teenage years on 160 AM!

**Jack Wheeler, KH6CC and  
Dean Manley, KH6B, Hilo, Hawaii**

## Practical and thorough...

Dear HR

Please let me report that John Piunichny's article on the dual eccentric capacitor drive ("Near Linear Tuning with Dual Eccentric Pulleys," January 1990) is the best article I've seen in the ham radio journals for a good long time. Let me also suggest that articles of this practical value and thoroughness be printed as often as possible. I hope we see more contributions by Mr. Piunichny in the future.

**J. A. Smith, Hudson, Wisconsin**



# KENWOOD

## Weight-less!

### TH-26AT/46AT

144 MHz/450 MHz

#### Compact Portable FM transceivers

**Quick! Grab one before it gets away!** These new compact portables boast a whole set of brand-new features. The new DTMF encode/decode squelch system (DTSS) for selective calling, four 15 digit auto-dialer, DC direct-in capability (with optional PG-3F or PG-2W), versatile scanning functions, wide-range of DC power sources, 5 W capability, and an extensive list of exciting accessories make this radio the one to grab!

- **Frequency coverage:**

TH-26AT: 136-173.995 MHz;

TH-46: 438-449.995 MHz.

(TH-26AT modifiable for MARS/CAP.

Permits required.) TX on Amateur band only.

- **NEW! Dual Tone Squelch System (DTSS)** enables selective calling with 3-digit DTMF codes! The DTSS codes can be stored in channels 1-3.

- **Multi-function scanning.**

Band and memory channels can be scanned, with time operated or carrier operated scan stop.

- 21 memory channels. Store everything you need, including CTCSS and DTSS codes. Ten channels can store RX and TX frequencies independently for odd split operations.
- Frequency step selectable for quick QSY. Choose from 5, 10, 12.5, 15, 20, or 25 kHz steps.
- Five watts output when operated with PB-8 battery pack or 13.8 volts.
- Large top mounted LCD display, with night-light.
- Auto-dialer function. Four 15-digit DTMF codes can be stored for auto-patch use.

- **T-ALERT** for quiet monitoring. Tone Alert beeps when squelch is opened.
- Auto battery saver, and economy power mode to extend battery life.
- Automatic repeater offset.
- **Supplied Accessories:** Flex antenna, PB-10 battery pack (7.2 V, 600mAh), wall charger, belt hook, wrist strap, bottom cover.



#### Optional Accessories:

- **PB-5** 7.2 V, 200 mAh NiCd pack for 2.5 W output
- **PB-6** 7.2 V, 600 mAh NiCd pack
- **PB-7** 7.2 V, 1100 mAh NiCd pack
- **PB-8** 12 V, 600 mAh NiCd for 5 W output
- **PB-9** 7.2 V, 600 mAh NiCd with built-in charger
- **PB-10** 7.2 V, 600 mAh (works with BC-2 wall charger)
- **PB-11** 12 V, 600 mAh
- **OR** 6 V, 1200 mAh, for 5 W **OR** 2 W
- **BC-10** Compact charger
- **BC-11** Rapid charger
- **BT-6** AAA battery case
- **BT-7** AA battery case
- **DC-1/PG-2V** DC adapter
- **HMC-2** Headset with VOX and PTT
- **SC-24, 25, 26** Soft cases
- **SMC-31** Speaker mic.
- **SMC-33** Speaker mic. w/remote control
- **TSU-7** CTCSS encode/decode unit
- **PG-2W** DC cable w/fuse
- **PG-3F** DC cable with filter and cigarette lighter plug
- **WR-1** Water resistant bag

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Specifications, features and prices subject to change without notice or obligation.

# MFJ Grandmaster Memory Keyer™

More than user-friendly . . . it's really easy-to-use



MFJ-486

**\$189<sup>95</sup>**

Made in U.S.A.

**Simple . . . intuitive . . .** you instantly know which knob to turn, what button to press. It's unmistakable.

**That's** the MFJ Grandmaster concept -- more than user friendly . . . it's really easy to use.

**There's** no keypad, no complex keystroke sequences to confuse you.

**The** new MFJ-486 Grandmaster Memory Keyer™ gives you the best of both worlds -- all the features you'll ever need and the easy-to-use MFJ Grandmaster concept.

#### Exclusive CW Word Processor™

**MFJ's** exclusive CW Word Processor™ lets you change a message in memory without having to rekey it all in.

**Special** function keys make it simple to move around within any message, insert, delete and change your message until it's just the way you want it.

**With** other memory keyers you have to erase an entire message and rekey it all in to make even the smallest change.

#### Combine messages into other messages

**The** MFJ-486 lets you combine frequently used messages into other messages.

**You** can store QTH, rig/antenna, QSL info and other comments in separate memories.

**Then** you can easily build a new message by keying in memory numbers wherever you want that info in your message.

#### MFJ's Custom-Speed™ Control

**Customize** your speed control to fit you!

**By** pressing the Speed Set button, you can set your slowest speed to start at 4, 5, 6 -- any speed up to 20 WPM -- and your fastest speed is 20 to 100 WPM.

**Matching** CW speed to a QSO is best done by ear as you adjust a speed knob.

**With** keypads you have to figure out the exact speed of your contact and then go through an awkward keystroke sequence.

**That's** why matching speed with a

keypad is so demanding.

**Without** MFJ's Custom-Speed™, a wide range speed control is very hard to use because the *slightest* touch causes radical speed changes.

#### Built-in CW Course

**The** MFJ-486 gives you a well-organized three step CW course for upgrading and teaching.

**The** first step gives you random five character groups. After you learn the letters you can add punctuation.

**The** second step gives you random 1-8 character groups for real-world code practice.

**The** third step gives you an infinite number of random plain English QSOs in the same format as FCC ham license tests.

**When** you can copy these random QSOs, you're ready to pass your test and upgrade!

**You** also get Farnsworth option, answer-replay to check your copy, punctuation on/ off and earphone jack for private practice.

#### Remote Control . . .

for memories and function keys

**The** MFJ-77 remote control lets you control your message memories and CW Word Processor™ function keys at your key paddle for only . . . \$19.95.

**It's** a lot more useful than a remote that gives you no editing functions and only lets you control a few memories.

#### MFJ Keyers are used year after year

**Not** so long ago there was a glut of keypad keyers. They were novel, and a lot of hams spent their money.

**But** because they were hard to use they ended up in drawers and closets.

**They** were soon no longer made.

**Most** original MFJ keyers are still being used -- day after day and year after year.

**Why?** Because they're easy-to-use. And that's why more new MFJ keyers are being put on-the-air today than ever.

#### More for your money

**To** make it really easy-to-use, it cost more to build the MFJ Grandmaster.

**It** just takes more hardware -- knobs to turn, buttons to press, LEDs to show

you what's going on. Plus it takes more labor, more software, more everything.

**It's** a real bargain compared to cheaper-to-build but harder-to-use keypad keyers.

#### Plus More . . .

**You** get over 8000 characters in 10 soft-partitioned memories -- far more than you'll ever need.

**You also get . . .** lithium battery backup, automatic serial numbering, automatic message repeat, beaconing, A or B type iambic keying, manual or automatic word spacing, speaker, earphone jack, easy-to-use front panel controls for speed, volume, tone, weight and delay, tune control, powerful Z-80 microprocessor plus much more. 9x2 1/2x6 inches. Use 12-15 VDC or 110 VAC with MFJ-1312, \$12.95.

#### One Full Year

No Matter What™ Guarantee

**You** get MFJ's full one year no matter what™ guarantee.

**That** means MFJ will repair or replace your MFJ-486 (at our option) no matter what happens to it for a full year.

**Others** give you a 90 day limited warranty.

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# SKYWAVE COMMUNICATIONS PART 1

## A brief account of the propagation phenomena

By Cornell Drentea, WB3JZO

*"To account for the transmission of waves through space containing no ordinary matter it seems necessary to assume the existence of a universal medium filling all space and even interpenetrating matter itself."*

From *A Text Book of Physics*, by A. W. Duff, circa 1908.

### The ether

If radio signals were transmitted in free space regardless of their frequency, they would appear to propagate along straight lines, only to be curved by time itself within the theory of quantum electrodynamics. Within this concept, waves from a transmitter's antenna (providing that a true omnidirectional pattern could be obtained) radiate an electromagnetic field in the entire space surrounding it. In this ideal case, a receiving antenna in its field would receive a certain amount of the transmitted energy, which would be inversely proportional to the distance from the transmitter. That is, power flux degrades inversely as the square of distance from the transmitter point. Propagation would then be defined as the transfer of energy without the transfer of matter. This is the modern theory of free space propagation.

However, this theory wasn't always known. Until recently, scientists believed that in order for electromagnetic waves to propagate, there had to be a medium (versus a vacuum) — just as air or some other medium is needed for mechanical sound propagation. For some time, it was believed that a certain exotic substance called "ether" filled the universe. The ether theory came about in 1865 when the British physicist James Clerk Maxwell described mathematically how wavelike disturbances in the combined electromagnetic field would travel at a fixed speed. The speed of light was first measured in 1676 by the Danish astronomer Ole

Christensen Roemer. He observed differences in events happening with Jupiter's moons which led him to the conclusion that light travels at a finite speed. Imprecise measurements taken at the time indicated that this speed was 225,308 km per second (or about 140,000 miles per second) rather than the modern value of 300,000 km per second (or about 186,000 miles per second).

Maxwell showed that if the distance between the wave peaks (the wavelength) is a meter or more in length, you have radio waves. Consequently, shorter wavelengths would be known as microwaves, infrared, visible light, ultraviolet, x-rays, and gamma rays.

Maxwell's theory was very advanced and accounted for the present theory of relativity which says, among other things, that light travels at a finite speed. However, at the time, an older Newtonian theory existed which said that the speed of anything was to be measured relative to something fixed — just like the speed of sound in the air.

It was then suggested that electromagnetic energy was propagating through the mysterious substance, and that the speed of electromagnetic energy was measured against this fixed ether. As a result, different observers moving relative to the ether on two separate points on earth would perceive light coming toward them or moving away from them at different speeds, but the light speed relative to the ether always remained fixed. According to this theory, as the earth was turning around its axis and floating in ether, the apparent speed of light from a single source was higher or lower — depending upon the location of the observers. But experiments carried out in 1887 by Albert Michelson and Edward Morley at the Case School of Applied Science in Cleveland, Ohio indicated that the speed of light observed in the direction of earth's rotation was exactly the same as that at right angles to the earth's motion.

This defeated the mechanical wave propagation in the air model and, of course, the ether theory. It was proven soon after, in a famous paper written in 1905 by a clerk named Albert Einstein of the Swiss patent office, that the

whole theory of ether was unnecessary if one was willing to abandon the idea of absolute time. Thus, the theory of relativity was born. Einstein's theory said simply that the laws of physics should be the same for all free moving observers, no matter what their speed. Since then the term ether has been used only to recall our naive vision of the universe during those beginning radio days. (Our knowledge today may still be naive in view of what we will learn tomorrow.)

## Electromagnetic wave propagation on earth

I have discussed how, in the ideal propagation model, a space-transmitted RF signal leaves the antenna and propagates in all directions without the help of ether. This energy would be received at a point located on an infinite number of imaginary spheres surrounding each other like the layers of an onion. There is a big departure from this simple concept when you look at what actually happens to wave propagation on earth. First, these ideal spheres are broken up by the earth's mass and magnetic field, so the ground may indeed act as part of the transmission circuit. This interaction usually results in losses which diminish the groundwave with distance. We know today that different ground conditions provide different degrees of attenuation. For example, over a good conductor like seawater, absorption tends to be minimal for very low frequency (VLF), low frequency (LF), and some medium frequency (MF) waves — a condition used to enhance maritime services ranging from 10 to 100 kHz.

In addition, depending on the frequency of an RF signal, complex and not entirely predictable interaction with the composition of the earth's atmosphere exists due to the sun's indirect meteorological impact. Things are further complicated by the interaction of the sun's radiation with the matter in the atmosphere. This is known as the ionospheric phenomenon and is further impacted by the earth's magnetic field. Propagation of high frequency waves on earth is therefore impacted, in addition to the free space loss discussed earlier, by the ionosphere absorption, dispersive loss, and by ionospheric focusing and defocusing.

## The short path and the long path

The shortest possible communication route between any two points on earth follows a curved path around the earth between the two points. This is known as the short path. The line is part of an imaginary circle drawn around the earth's curvature, called the great circle line. This line touches the two points and is an extension of the short path. The longer route between the two points on the great circle line is known as the long path. Finding the great circle line of any two points on a globe is easily achieved by stretching a rubber band around the globe and touching the two points. With the earth's circumference of 38,624 km (24,000 miles), there will be only one instance in which the paths are equal; that is, when the two points are 19,312 km (12,000 miles) away from each other. In all other instances, there will always be a short and a long path. In general, the short path is used for communications, but not necessarily via direct waves. Long path communication occurs if low angle ionosphere reflections and refractions exist, and there is evidence that both paths can be engaged at the

same time in high frequency (HF) communications. The propagation via the two paths and the ionosphere is defined as skywave communication.


## The challenge of predicting propagation

In general, HF radio communication depends upon the ability of the ionosphere to reflect the transmitted radio energy back to earth over the short and long paths. Although this is a well-known concept, predicting the degree of ionization in the various regions of the ionosphere, anticipating the expected skywave signal at any point on earth, and comparing this information with the expected local radio noise environment at a particular time, have been the subjects of much work intended to prove the reliability of radio circuits. This work has also had an additional impact on the design and development of radio communications receivers.

The prediction of ionospheric performance has been based mostly on empirical work. The problem lies in properly defining ionospheric absorption equations and combining them with the theoretical ground loss, dispersive loss, free space loss, power focusing and defocusing, and antenna gain factors. This is further aggravated by the effects of solar activity, and the seasonal and diurnal variations.

Despite all these difficulties, computer models of parabolic distribution (the ionosphere looks like a concave mirror from earth) of electron density have been developed along with new concepts. In addition to the great circle line-single ray concept discussed earlier, these concepts concern such new things as complex azimuth diversity and coverage by stochastic (refers to independence of events of random variable nature) scattering phenomenon.

The art of HF propagation prediction has been furthered by field tests and backed by a worldwide network of vertical incidence ionosondes intended to measure the diverse parameters at heights of up to 300 km (186 miles). Additional work has been performed at Arecibo Observatory with a new technique known as incoherent scatter observation (observation of the scattering of the transmitted waves by the individual electrons in the ionosphere). This technique allows scientists to observe the ionospheric conditions to heights of about 1,995 km (1,240 miles). Heating and artificial excitation of the ionosphere have also been done through the observatory's ionospheric modification facility (nicknamed "the heater") near Arecibo. This facility has 58 acres of log-periodic antennas powered by an 800-kW transmitter which can concentrate energy in the atmosphere at wavelengths of 20 to 200 meters. The heated electrons and their interaction can then be studied by the 1,000-foot radio telescope. Worldwide radio noise measurement records have been compiled since 1963 in a famous report entitled "World Distribution and Characteristics of Atmospheric Radio Noise."<sup>1</sup>

Despite all these advances, the science of propagation prediction remains an inexact one. In part 2, I'll look at what is known about the ionosphere. 

### REFERENCE

1. "World Distribution and Characteristics of Atmospheric Radio Noise," Comité Consultatif International des Radiocommunication, CCIR Report no. 322, International Telecommunication Union, ITU, Geneva

### The Night of the Aurora

It was a beautiful clear night in October 1989. The Indian summer was still with us here in Lake Wobegon country, and a full moon was majestically displayed over the cold evening sky. The smell of leaves made me think of the Minnesota winter just around the corner. Suddenly, I felt isolated from the rest of the world and overcome with a strong desire to search the ether for other lonely beings. Tuning across the bands produced a couple of short contacts, but signals were faint and rubbery — like weak, fluttering voices at the end of a tunnel. I could still hear a faraway storm crushing its way through the south. And then...it all turned to silence. There was nothing but a slowly growing noise which covered every band. My digital clock showed 3:17:30 a.m. when I decided to listen to the propagation bulletin just coming up on my WWV receiver. But I couldn't hear anything there either. I thought this must have been the way the bands were before the days of radio, filled only with pulsating noise which took over everything. Through the window I could now see a growing purple light, which at times seemed brighter than the light coming from the moon. "It must be Aurora Borealis," I determined as I turned off all radios and rushed out into the yard. And there it was: majestic, right above my head with long purple drapes extending all the way to the ground; it seemed I could almost touch them with my bare hands. I had an overpowering electrical feeling which I have experienced only once before, while watching fireball lightning at sea during an electrical storm in the tropics. The light was waving slowly and changing colors. Then it stopped for a moment, only to start moving again.

I rushed in for my camera and tripod. (The result appears on the cover of this issue. Ed.) Like any picture, it can only express a fraction of the original feeling I experienced when I took it. I wrote this story in an effort to share the experience. The work which accompanies it is intended to further your knowledge about the sun and ionosphere, and how they affect radio communications. Although much has been written on the subject of propagation, this three-part article will stick with the scientific base. I intend to clarify the concepts of HF communications rather than chronologically list data. Because the subject is so vast, I chose to emphasize certain technical areas that cannot usually be found in one single publication, and combine them with facts and experiences of my own. The work begins with the free space propagation concept, concentrates on complex ionospheric physics made simple, and concludes with a discussion on tools for predicting propagation. In presenting the propagation software at the end of part 3, I do not make any claim as to performance, nor am I an agent of any of the companies involved. Anyone interested in obtaining more information about this software should contact the producers directly, or obtain the information from advertisements.

de WB3JZO

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# ANOTHER LOOK AT HF MOBILE ANTENNAS

By Jack Najork, W5FG, 723 Flamingo, Duncanville,  
Texas 75116

**A**fter reading NCØB's excellent article on HF mobile antennas in *Ham Radio's* September 1989 issue,<sup>1</sup> I was inspired to look up some data I recorded many years ago on inductively loaded mobile antennas. I'd like to offer some additional thoughts on this subject.

### Loading coils

It has long been stressed that HF antennas requiring inductive loading should use high Q, low loss coils. This concept is employed in the "bug catcher" type coil. The coil is perhaps 3 to 5 inches in diameter and space wound with no. 12 or no. 14 wire to give the optimum form factor for maximum Q. A length-to-diameter ratio of 0.4 to 0.5 results in the shortest length of wire and, therefore, the lowest RF resistance for a given inductance.

While this form of loading coil is generally an improvement over some commercial designs, it's not the optimum when used as part of the overall mobile radiation system.

Tests indicated that the Q factor of the coil is secondary to its *physical shape*. A long, narrow coil (still low loss) of lower Q consistently produced a stronger radiated signal than the short, fat, high Q coil when all other factors of the system were equal.

### Shape versus Q

One theory for the superiority of the long coil was given by E.L. Gardiner, G6GR, in *Radio Communication*.<sup>2</sup> He pointed out that any radiated field in space must have both an electrostatic and an electromagnetic field which are correctly related. Neither field by itself will produce meaningful radiation.

In the typical loaded mobile whip, current in the lower section generates a magnetic field. This field won't be radiated unless an adequate electrostatic component is also present in the form of an RF potential difference between the ends of the conductor carrying the current; that is, the base and tip of the whip. These components will be in phase because the antenna is a resonant circuit. The major portion of the potential difference appears across the ends

of the coil, as is normal in a parallel-tuned circuit. The electrostatic field strength setup is proportional to the distance between these two high potential points — namely, the length of the coil.

For example, 100 volts across 1 meter represents an electrostatic field of 100 volts per meter, while the same potential across 1 centimeter represents only 1 percent of this field. This leads to the conclusion that however strong the electromagnetic field component may be, it can be fully transformed into radiation instead of heat only if an adequate electrostatic field is present, and vice versa.

### Practical considerations

From a practical standpoint, the optimum length for this type of loading coil is 14 to 20 inches for 160 meters and 10 to 14 inches for 75 meters, with corresponding diameters of 1 to 2 inches. The lower wind resistance of such a coil allows it to be located higher up on the vehicle. This places the radiated field away from the car body and reduces losses.

For maximum radiation and efficiency, the loading coil should be placed as high above the vehicle as possible. I have seen bug catcher type coils mounted on vans with a spacing of a foot or so from the metal body — a sure method of converting most of the RF to heat instead of radiation.

It isn't difficult to homebrew efficient mobile antennas. You can use any sturdy material for the bottom section. I use fiber glass wound with copper tape. I also use fiber glass for the top section. My loading coil forms are polyethelene bottles of the desired diameter. I remove the top and bottom of each bottle to produce a hollow form. I use foam tape on the fiber glass whip to build it up to a diameter which is a snug fit for the top and bottom of the form. For 75 meters, you may need two forms situated one above the other. After winding, cement the coil to the taped segments. Because the fiber glass whip passes through the coil, it receives very little physical stress. This method also eliminates the need for any large metal fittings near the field of the coil which would reduce Q. The only metal parts near

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the coil are two 4-40 brass bolts and nuts used to anchor the ends of the winding.

Coils are space wound with no. 18 wire for 75 meters and no. 16, 14, and 12 for progressively higher frequency bands. If you use fiber glass for the complete top section, make the segment conductive by slipping on braid from coax cable. Because you want maximum capacity above the coil, cover the entire surface of this section with the braid. A single piece of wire (no. 14, for example) taped to the fiber glass will work but the capacity will be lower, requiring more inductance on the coil.

After you prune the coil to frequency, give it a layer of PVC tape for weatherproofing and to eliminate "bug catching" between turns. Drill several holes through the layers of tape at the bottom to let the inside of the coil breathe and to prevent moisture buildup.

Please note that this is a single band antenna. I change bands by changing top sections, each of which is optimum for one band. The inconvenience of changing top sections is offset by the "home station" reports I receive.

### Tuning the antenna

Commercial mobile antennas are generally close to resonance and require only slight adjustment of the top section to bring them on frequency. Homebrew antennas, however, can initially be megahertz away; this can pose a tune-up problem.

The usual method of finding resonance involves coupling a grid dip oscillator (GDO) to a one-turn loop connected between the base of the antenna and car body (ground). You then find the frequency of the GDO on a calibrated receiver.

If you don't have a GDO, you can get the same results with a 79-cent Radio Shack buzzer and some flashlight cells. Couple a loop from the buzzer-battery connection to the loop at the base of the antenna. Temporarily shield the buzzer by sticking it in a cake tin or wrapping it in foil. With the buzzer fired up, the antenna will be shock excited and radiate a weak, raspy signal at its resonant frequency. You'll be able to pick up this signal on your receiver. If the band is busy, you may need to run a piece of coax from the receiver to the vicinity of the antenna to pick up antenna radiation only. This system works best on the lower frequency bands where the Q of the antenna is higher, with buzzer noise peaking over a 20 to 30-kHz segment of the band.

After you fracture your rib cage laughing at this scheme, I'll tell you that I filched the idea from the broadcast industry. In the days before fancy instruments, the same system was used to determine the resonant frequency of scaled broadcast towers. If your library is as old as mine, you'll find this technique in *The Radio Engineering Handbook* by Keith Henney.<sup>3</sup>

After you determine the resonant frequency (hopefully at a lower than desired frequency) remove turns from the loading coil, one at a time, until you observe resonance on the high frequency end of the band you want. Turns must be removed, not shorted; a shorted turn will lower the Q of the coil.

On 160, 75, and 40 meters, it's easiest to retune to lower frequencies with a remotely controlled roller coil in the car trunk, as described by K9MLD in *Ham Radio*, October 1988.<sup>4</sup> I used this system back in the fifties running 35 watts

AM on 75 meters and can vouch for its convenience. The secret of efficient operation is to peak the antenna alone at the high frequency end of the band and then use just enough roller coil inductance to restore resonance on lower frequencies. Because the roller coil is bottled up in your trunk, any radiation it produces isn't going anywhere, so use as little inductance as possible. The best resonance indicator for this system is a field strength meter at the driver's position; this will quickly tell you when the system is peaked to maximum output.

Some homebrewers use a sliding section type whip above the coil to tune. Unfortunately, the conventional auto type collapsible whip will quickly develop intermittent contact at the sliding joints, resulting in noisy reception and erratic loading on transmit. Sliding joints are recommended only if you devise some way of fastening them securely after adjustment via a set screw to ensure low loss continuity. Even a few watts of RF power will affect joints in this manner — they just aren't designed to pass RF current.

In lieu of a roller coil, you can make limited excursions lower in frequency using an alligator clip and a short (2 to 3 inch) piece of wire clipped above the loading coil to increase capacity. After a few trials, you can readily determine where to locate the clip in order to hit the desired band segment.

### SWR

No story on antennas is complete without a discussion of SWR. I may shock the majority of you by saying that the usual obsession with a low SWR doesn't really apply to mobile HF antennas. Other than to satisfy a fussy solid-state rig, a low SWR isn't essential. In some cases it's actually detrimental.

Your objective is to obtain maximum radiation from an antenna system which is, by its physical properties, relatively inefficient. The fallacy of striving for a low SWR lies in the fact that you can doctor the antenna to produce a low SWR and, in so doing, actually reduce the effective radiation of the system. The best method of tuning a mobile antenna is with a field strength meter, adjusting for maximum radiation. Once you've done this, you can check the SWR. On the lower frequency bands it can be 2:1, or even 3:1. Because most transmission line runs on mobiles are short (less than 20 feet), the losses incurred from such ratios are negligible. If your solid-state rig doesn't like this condition, a simple "L" network at the rig will make things right.

It's entirely feasible to use inductive or capacitive matching devices at the feedpoint (base) of the antenna to improve the SWR. However, these are generally one-band devices requiring readjustment for each band. So, if you're an SWR fanatic, you can use base matching or an "L" network. But remember that each requires attention for a band change.

### The interstate bonus

For the crowded 20-meter band, I built two top sections. For in-town use I have a shorter section with a total height of 9 feet. On the interstate, where most overpasses are at least 14 feet, I go to a longer top section with the loading coil 10 feet above ground and a total height of 13 feet. This begins to look like a full quarter wave, and with my 100-watt homebrew mobile, performance begins to approach home station efficiency. The real interstate bonus comes



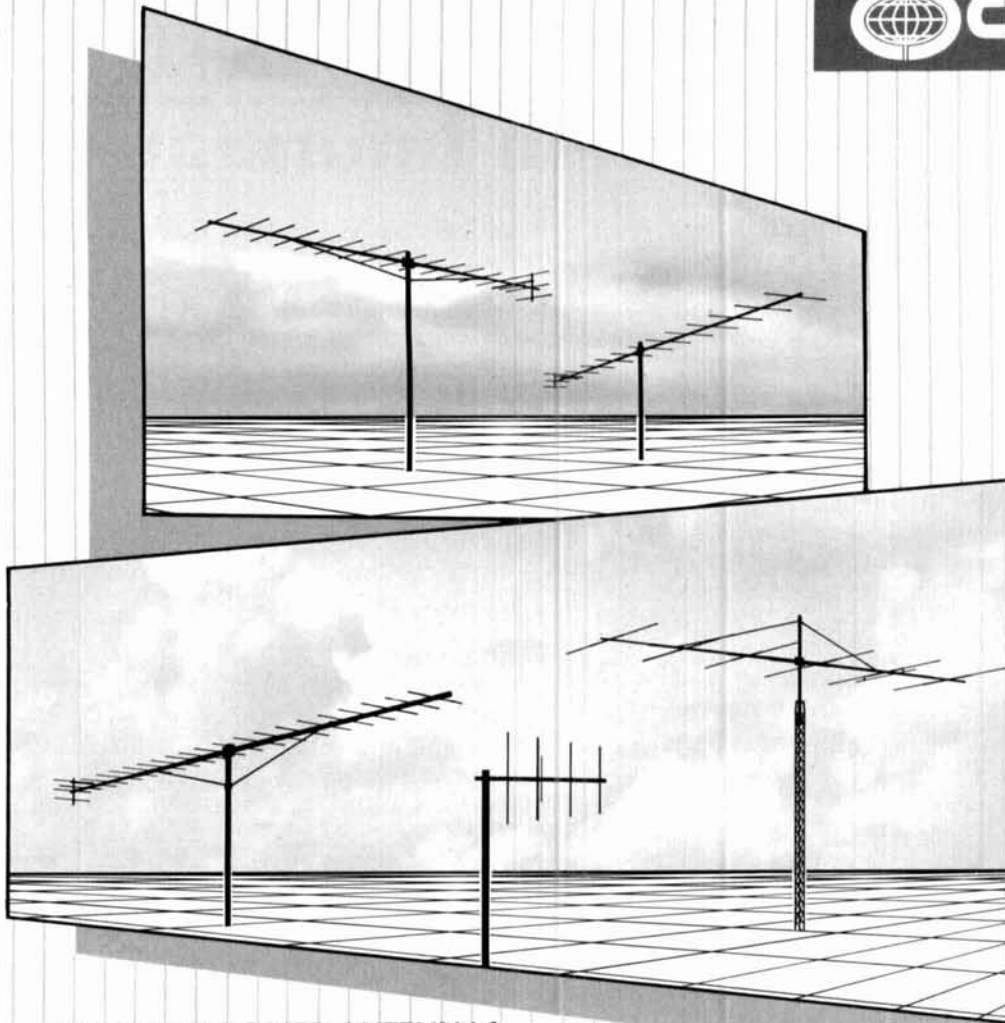
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courtesy of the highway's construction. With their large masses of steel reinforcing bars under the concrete, these highways constitute an excellent ground system which improves mobile operation significantly. It's the next best thing to driving over salt water (using a bridge, of course), so don't be surprised to find that signals drop suddenly when you leave the interstate for a country road!

You can always improve your mobile antenna system by becoming a fixed mobile. When parked at an off-the-road site, clip a quarter-wave length of wire to the *bottom* of the loading coil and throw the other end up into a nearby tree. This is most effective on 75 and 40 meters where antenna efficiency is lowest.

One ham I know kept an important 40-meter sked with this system. Unfortunately, he was out in west Texas and there were no trees around, so he had his XYL hold up the far end of the wire with his fishing pole. Needless to say, the QSO was short. 

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3. Keith Henney, *The Radio Engineering Handbook*, 4th Edition, Chapter 14, page 613
4. Joel Eschmann, K9MLD, "The Weekender, Remote Tuner for 75-Meter Mobiles," *Ham Radio*, October 1988, page 36

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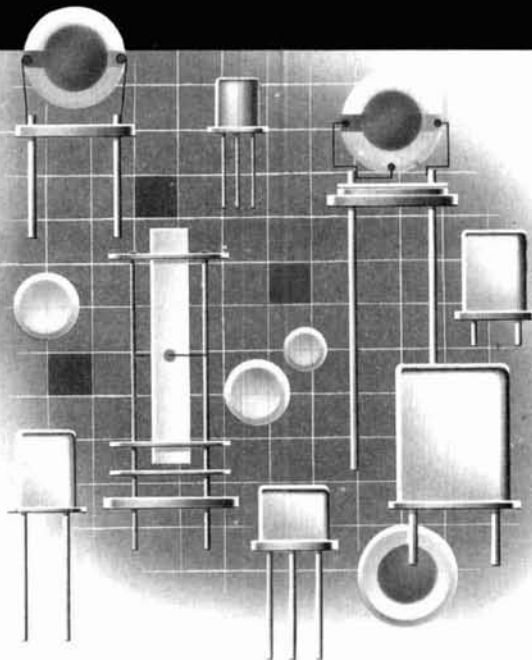
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# Microwaves

Bob Atkins, KA1GT

## LASER COMMUNICATION SYSTEMS

Over the last year or two it seems that a growing number of Amateurs have been building laser communication systems. This is probably the result of two factors. First, the availability of surplus lasers is increasing while the cost is decreasing. Second, many of the VHF/UHF/Microwave contests now award extra points for laser contacts. Last fall at the Mid-Atlantic States VHF Conference I gave a talk on laser communications which seemed to generate a lot of interest, so I thought I'd cover laser communication systems in my first few columns. Understanding how to build and operate such systems requires knowledge of three factors: laser transmitters, laser receivers, and atmospheric effects on laser propagation. While a number of complex heterodyne laser communication techniques are possible, they are out of the realm of Amateur operation, so I'll deal only with simple direct detection systems here. This month I'll discuss the laser transmitter end of the link.

I think a little historical background would be useful. In 1917 Einstein postulated — as part of his theory of blackbody radiation — that when an atom in an excited state was hit by a quantum of radiation, it could be induced to emit radiation with the same frequency, phase, and direction as the incident quantum. The original incoming quantum of radiation isn't absorbed and amplification has been achieved because one radiation quantum has now become two. This process is known as the stimulated emission of radiation. The first practical use of this process came in the invention of a microwave amplifier in the early 1950s. This device was the MASER, which stands for Microwave Amplification by Stimulated Emission of Radiation. Later, the same principle was applied to optical frequencies and the optical maser was developed. This is now called the LASER, and stands for



Light Amplification by Stimulated Emission of Radiation. Most lasers are used as light sources rather than amplifiers by using positive feedback (more on this later).

The many different types of laser are usually classified by the nature of the lasing medium. This medium can be a gas, liquid, or solid. The lasers which show up on the surplus market are almost always gas lasers. A mixture of helium and neon make up the lasing material. They are known as helium-neon or He-Ne lasers. Semiconductor lasers also show up from time to time, but they are generally less useful for DX communications purposes, so I won't deal with them here. The basic construction of a typical He-Ne laser is shown in **Figure 1**. A hollow glass or ceramic tube is closed off at each end by mirrors and filled with a mixture of helium and neon. One of the mirrors is 100 percent reflective; the other is only partly reflective, allowing some light to pass through. An electrical discharge is then set up in the tube, exciting some of the neon atoms. A few of these atoms emit light quanta through a process known as spontaneous emission. These light quanta can then collide with other excited atoms, caus-

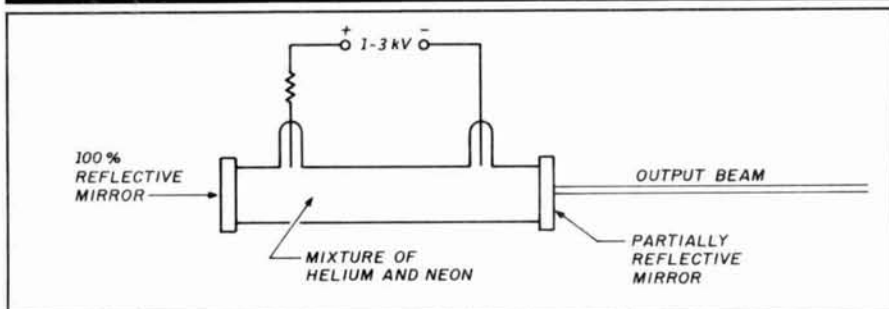
ing stimulated emission (the amplification process) in the same direction as the incident quantum. Because there are mirrors at the ends of the laser tube, light quanta are reflected back and forth along the tube making many collisions with excited atoms in the process. This further amplifies the light and sustains the emission process through positive feedback. A small amount of light leaks out through the partially reflective mirror; this is the output laser beam. The wavelength of the output light is determined by the composition of the gas in a laser and the design of the tube and end mirrors. He-Ne lasers are normally designed to emit red light at a wavelength of 632.8 nm, but they can be designed to emit green light or even infrared radiation at lower efficiency. Other gas lasers, like the helium-cadmium (He-Cd) and argon (Ar), emit light mainly in the blue and blue-green regions of the spectrum. Note that the nature of the light output by a laser is usually characterized by its wavelength. A number of units are commonly used. They are:

Nanometers =  $10^{-9}$  meters  
Angstroms =  $10^{-10}$  meters  
Microns =  $10^{-6}$  meters

The frequency of the output beam is rarely, if ever, used. Thus the red beam from a He-Ne laser can be characterized as one of the following, all of which are equivalent:

632.8 nm (nanometers)  
6328 Å (angstroms)  
0.6328 μ (microns)

**FIGURE 1**



**Simple He-Ne Laser.**

Expressed as a frequency these become:

474.35 THz  
 474,350 GHz  
 474,350,000 MHz

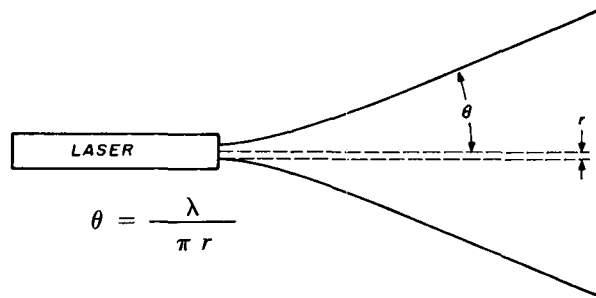
Most of the He-Ne lasers on the surplus market have a power output of 1 to 5 mW, which is quite adequate for even long range DX contacts. Prices range from \$40 to \$200 depending on power output and condition.

A laser beam has several properties which distinguish it from other light sources. It consists of light of a single wavelength (or a very narrow wavelength range), in contrast to light from a flashlight which emits light over a very broad wavelength range. For an RF analogy, you might equate the laser with a single frequency crystal-controlled carrier, while the flashlight would be analogous to the output from a noise diode or even a spark transmitter! A second important characteristic of the output beam from a typical gas laser is its very small divergence (beam spreading). Even at a distance of about a mile, the beam from a small He-Ne laser spreads only to a diameter of 5 feet. A third unique feature of laser light is that it is coherent; that is, every light quantum, or photon is emitted in phase. This is very important in certain laser applications, like holography, but isn't a requirement for efficient DX communication.

From the standpoint of DX communication, perhaps the most important feature of the laser is the low beam divergence. The laws of physics indicate that all beams diverge, no matter how perfectly collimated (parallel) they are to start with, as a result of diffraction. The degree of divergence is directly related to the beam diameter — the larger the beam, the lower the divergence. A radio analogy can be found in parabolic antennas. A very large antenna produces a very wide initial beam with a very small beamwidth (divergence), whereas a small antenna produces a small initial beam with a large beamwidth (divergence). You can also look at this as a consequence of diffraction. The same equations govern both the spreading of a laser beam and the beamwidth of a parabolic dish. The geometry of diffraction spreading is shown in

Figure 2.

FIGURE 2



where  $\theta$  is the beam divergence in radians. (1 radian  $\approx$  57.3°)

$\lambda$  is the wavelength

$r$  is the beam radius

( $\lambda$  and  $r$  are measured in the same units.)

For a He-Ne laser with a 1-mm diameter beam.

$$\theta = \frac{6328 + 10^{-7}}{(\pi) + (0.5)} = 4.03 + 10^{-4} \text{ Radians}$$

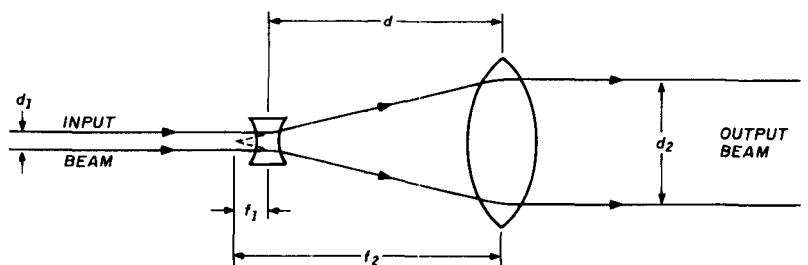
Total beam divergence = 0.806 mR or 0.046°

Diffraction limited beam spreading. Both  $\theta$  and  $r$  are measured at the point at which the beam has an intensity of

$$\frac{1}{\ell} \left( \frac{1}{2.7} \right)$$

the intensity in the beam center (assuming a Gaussian beam).  $\theta$  then corresponds to the 4.3-dB beamwidth of the beam.

FIGURE 3



$f_1$  = (negative) focal length of diverging lens (input)

$f_2$  = (positive) focal length of converging lens (output)

Beam expansion =  $f_1/f_2$

Lens separation =  $d = f_2 - f_1$

With an input lens of focal length (-) 1 cm

and an output lens of focal length 4 cm:

The beam will expand by 4x.

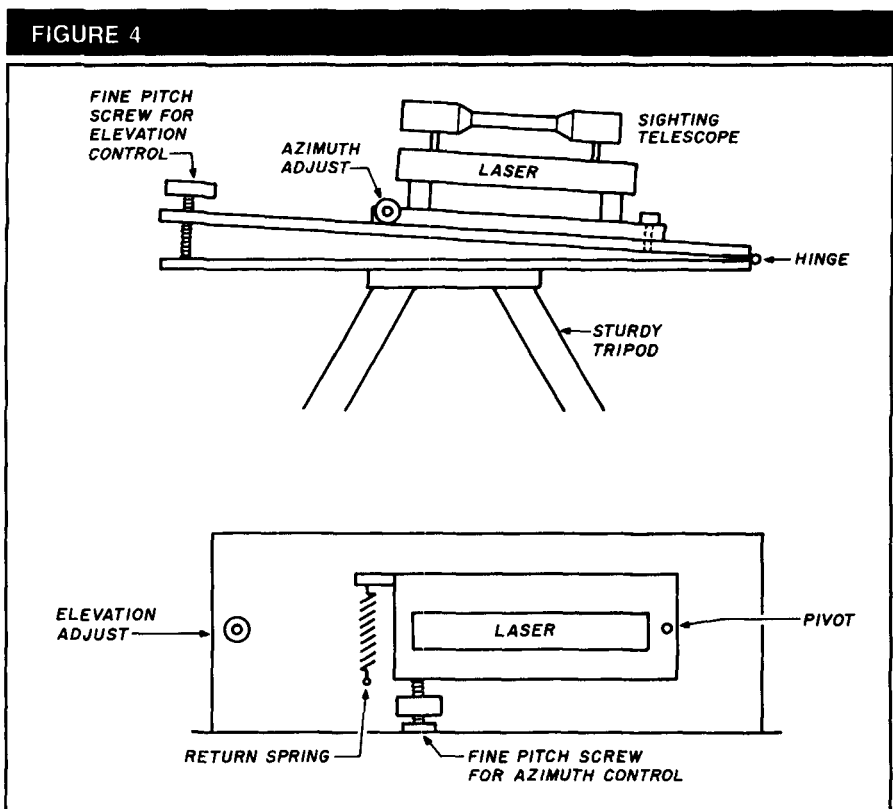
The lens separation will be 3 cm.

Laser beam expander.

Increasing the beam diameter of a laser is analogous to using a higher gain antenna. Optically this is accomplished by means of a beam expander, as shown in **Figure 3**. This is akin to a Galilean telescope used in reverse; that is, the beam enters through the eyepiece and exits through the objective. While such a decrease in beam divergence may be desirable for DX communication, it is not without significant problems. Most small He-Ne lasers have an intrinsic beam divergence of about 1 milliradian (1/20 degree). This means that the laser must be pointed at a distant receiving station with an accuracy of better than 1/20 degree. If the beam is expanded five times, the beam divergence drops by a factor of 5, and the required pointing accuracy becomes 1/100 degree. Obtaining such a pointing accuracy isn't an easy task. It requires a very solid mounting system and a capability for very fine positional adjustment, not only in azimuth but also in elevation. You can achieve this by using a system like the one shown in **Figure 4**. You can also try adding a sighting telescope as an alignment aid.

In order to transmit information via a laser beam, you must achieve some form of beam modulation. Mechanically interrupting the beam is the simplest, cheapest, and most efficient modulation scheme. At reasonable CW speeds you can do this using a solenoid operated shutter. This would correspond to A1A emission using the WARC '79 scheme. Alternatively, you can modulate the beam at an audio frequency by passing the beam through a rapidly rotating wheel with slots cut in it (try the blades of a fan). This modulated beam can be keyed on and off mechanically. This is modulated CW (MCW), or A2A modulation, under the WARC '79 designation. The advantage of using MCW is that it lets you use a simpler receiver system which I'll describe later.

If you want analog (voice) or high speed digital modulation, there are a couple of ways you can accomplish it. The preferred method is to use an acousto-optic modulator. This device is made up of a special type of crystal which is acoustically modulated at a very high frequency (several MHz) by the application of an RF field. The process is similar to the piezo-electric effect exhibited by quartz crystals. This acoustic modulation sets up standing



**Azimuth-elevation mount for laser. Note: The greater the pivot-azimuth screw and hinge-elevation screw distances, and the finer the screw pitches, the better the fine adjustment capability. Never point laser at any person, animal, or vehicle.**

pressure and density fluctuation in the crystal which can diffract a laser beam passing through it. As a result, a single input beam is diffracted into two (or more) output beams. The relative intensity of the power in the beams is a function of the RF modulating power. When the RF power is modulated, the output beams are amplitude modulated. While this method is capable of efficient and rapid analog or digital modulation (with bandwidths in excess of 1 MHz), its disadvantages are high cost (new acousto-optic modulators are \$500++) and the complexity of the drive electronics. Surplus equipment (from laser printers or FAX machines) containing acousto-optic modulators is sometimes available on the surplus market for \$50 to \$100.

A second method of amplitude modulation involves modulating the high voltage supply to the laser. This isn't very efficient because the maximum amplitude variation in the output laser beam is about 15 percent (typically it's much lower), but it can be done inexpensively. The reason for the low modulation amplitude lies in the discharge process in the laser tube. It operates somewhat like a common

neon bulb. A certain voltage is required to "strike" the discharge, but if the voltage is too high, the resultant high current will destroy the tube. Because the tube voltage must be held within quite tight limits, the resultant power output doesn't change greatly. The voltage modulation can be achieved by connecting one side of a well-insulated transformer in the lead carrying the high voltage to the laser tube. The other side of the transformer is then connected to an audio modulation source. You may need to experiment to find the optimum conditions for maximum laser modulation amplitude; some lasers may be more amenable to this type of modulation than others. Typical modulation levels will be on the order of a few percent.

There are numerous other modulation methods. These include: reflecting the laser beam from a small mirror attached to a loudspeaker, using transmission type liquid crystal displays (LCDs) as a shutter, and various kinds of magneto-optic and electro-optic devices (Kerr cells and Pockels cells). Though all of these methods can be made to work, they will generally be less convenient and less efficient than

beam interruption or the use of an acousto-optic modulator.

The small, 1 to 5 mW, He-Ne lasers found on the surplus market require power supplies which produce 1 to 2 kV at a current of a few milliamps. Because the current drain is so low, you can build a fairly simple power supply using diode and capacitor voltage multipliers. For portable use, try using a transistorized DC inverter to generate an AC output of a few hundred volts which can then be multiplied up to the required voltage. WA6EJO described such a power supply in the December 1986 issue of *Ham Radio*. Very compact encapsulated power supplies are commercially available. A power supply for a 2-mW laser which runs off 12 volts DC would be about 3 x 0.75 x 1 inches and would draw about 1 A. You can find commercial supplies running off 117 volts AC for around \$35; 12 volts DC supplies are more expensive at around \$90 and up.

While most of my comments have dealt with He-Ne lasers, other types of laser are also suitable for communications use. In fact, KY7B and WA7LYI used He-CD (blue) lasers to set a DX record of 95 miles in August 1988. I've concentrated on He-Ne lasers because they are by far the most common and least expensive lasers found on the surplus market. It's also true that red light will suffer less attenuation than blue light in its passage through the atmosphere. (I'll discuss this further in a future column.)

The final, and perhaps most important, point to be made about lasers is that they can be dangerous. Laser power supplies produce high voltages. Even though only low currents are involved, such supplies can be lethal. The output beam, though low in total power, has a very high power density. When focused through the lens of the eye onto the retina it can easily destroy tissue, causing partial or total blindness. The degree of danger is a function of the laser power. Lasers of less than 1 mW are generally safe, and even direct exposure to the beam isn't likely to be harmful. At power levels of 1 to 5 mW, the light is so bright that there's a natural tendency to blink and turn away from it, thus avoiding damage to the eye. At power levels of 10 mW and above, the blink/aversion response is often not fast enough to prevent injury. Remember that these are average effects in normal adults. Injury

thresholds of some adults, children, or animals may be lower. Of course, there's nothing special about lasers; any intense light source can be dangerous. Staring at the sun or an electric arc welder can also lead to eye damage. Responsible and safe handling of lasers is incumbent on all users; they aren't toys and should **never** be pointed at any person, animal, or vehicle.

The following is a list of surplus laser and laser equipment suppliers. It's not an exhaustive list, and inclusion or omission of any supplier does not imply endorsement or otherwise.

**MKW Industries**, 1440 S. State College Boulevard, Building 3B, Anaheim, California 92806. Telephone: (800)356-7714 or (714)956-8497. Laser surplus specialists. Lasers, power supplies, modulators, optic, books, and project kits.

**Edmund Scientific**, 101 E. Gloucester Pike, Barrington, New Jersey 08007. Telephone: (609)573-6259. New lasers, power supplies, and optics.

**Marlin P. Jones**, P.O. Box 12685, Lake Park, Florida 33403. Telephone (407)884-8764. Surplus electronics, some lasers power supplies, and optics.

**Heathkit**, P.O. Box 8589, Benton Harbor, Michigan 49022-8589. Telephone: (800)253-0570. "Laser Training System," 0.4 to 0.9-mW laser, power supply, and receiver. Laser can be amplitude modulated up to 10 percent.

**Jerryco**, 601 Linden Place, Evanston, Illinois 60202. Telephone (312)475-8440. Surplus electronics, optics, and miscellaneous items. Sometimes carries lasers and power supplies.

Those of you wishing to learn more about lasers might want to check out the following:

*The Laser Cookbook*, by Gordon McComb. TAB Books Inc., Blue Ridge Summit, Pennsylvania 17294-0850. Covers the basic principles of the laser, construction of laser power supplies, and a number of laser related projects (holography, light shows, fiberoptics, interferometry).

*Understanding Lasers*, Radio Shack 62-1333, \$4.95. Good introductory guide to the principles and operation of lasers.


"Communicating on 474,038 GHz," by Steve Noll, WA6EJO, *Ham Radio*, December 1986, page 10.

Next month I'll talk about optical receivers, including their design and

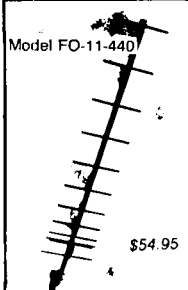
how to estimate sensitivity and "noise figure."

## Microwave product news

Avantek has recently announced a component which may be of interest to those building microwave equipment. It's an active double balanced mixer/IF amplifier, type IAM-81018, and is priced at \$38.90 (small quantities). The device is packaged in surface mount configuration (0.165 inch square) and consumes only 60 mW at 5 volts. For an RF (2 GHz) to IF (250 MHz) conversion gain of around 8 dB, only -5 dBm of local oscillator power is required. (From the spec sheet it looks as if operation with only -15 dBm LO power is possible with reduced conversion gain.) The IF output range is from DC to 1 GHz and the RF input range is from 50 MHz to 5 GHz. It appears that this device could be the heart of a multiband receive converter system, as it's a wideband device with 50-ohm input and output matching. The effective SSB noise figure at 2 GHz is 15 dB, so preamps would be required for good performance.

Well, that's all for now. Please send any questions, comments, or column ideas to me at 103 Division Avenue, Millington, New Jersey 07946. 

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Model FO-11-440

\$54.95

**ELECTRICAL SPECIFICATIONS:**

Measured gain ..... 12 dB

E-Plane beamwidth ..... 38 deg

H-Plane beamwidth ..... 42 deg

Sidelobe attenuation

1st E-Plane ..... -22 dB

1st H-Plane ..... -16 dB

SWR @ 1.5:1 440-450 MHz

V/S ratio ..... 21 dB

Impedance ..... 50 ohm

Polarization ..... Horiz. or vert.

**MECHANICAL SPECIFICATIONS:**

Length ..... 61" Rear Mount

Boom ..... 7/8" 6061 T-6 Aluminum

Elements ..... 3/16" Aluminum rod

Wind survival ..... 90+ MPH

Mast ..... up to 1.5" diameter

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# BUILD YOUR OWN SUPERCHARGER

## Charge 75 NiCds at one time

By W. C. Cloninger, Jr., K3OF, 4409 Buckthorn Court, Rockville, Maryland 20853

**H**andheld transceiver (HT), cordless screwdriver, rechargeable flashlight, extra HT battery pack, portable frequency counter, tape recorder... Do these items sound familiar? Most of them, and many other electrical devices, have something in common — rechargeable NiCd (nickel cadmium) batteries.

Most rechargeable devices come with their own charger, usually a small AC or DC wall transformer. They are generally single purpose. They charge a discharged battery to full charge, typically in 10 to 16 hours. They aren't designed for continued or trickle charging and may damage the battery if left on after the normal full charge period.

It's often desirable to keep NiCds completely charged and ready for use. Some of your rechargeable devices may sit for months before you use them. The solution to continual readiness is to keep your batteries on a maintenance or trickle charge.

Here's how to charge and trickle charge with the same unit. And why limit yourself to one charger? You can build a NiCd charger that will maintain the batteries in all of your rechargeable devices at the same time.

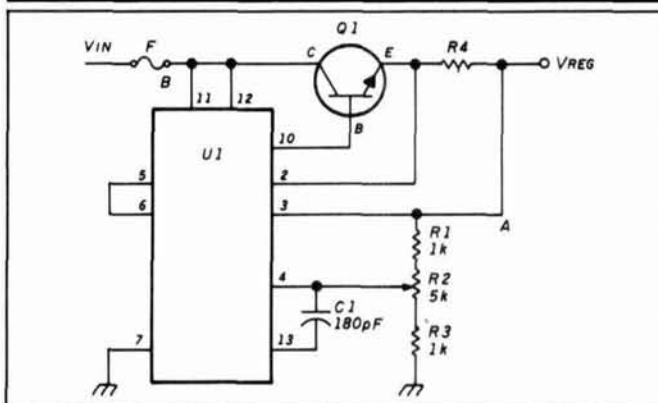
I've built a device that I call the Supercharger. The one shown in **Photos A** and **B** will charge and/or trickle 75 or more NiCds spread among up to six different rechargeable devices!

**Photos C** through **E** show the Supercharger in various stages of assembly to give you an idea of parts placement and wiring arrangement.

### Theory of operation

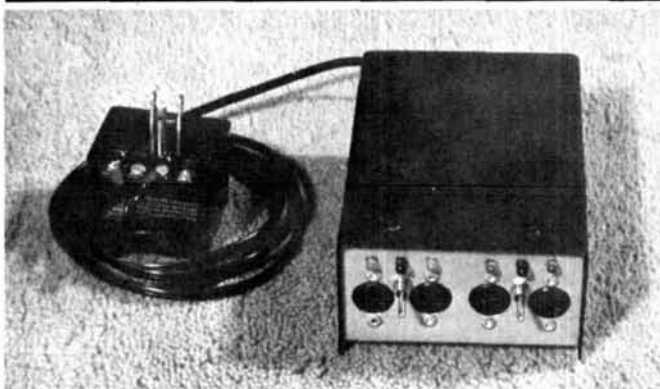
The basic building block of the Supercharger is a simple DC power supply with current limiting and adjustable voltage. The circuit shown in **Figure 1** uses the popular 723 voltage regulator. This regulator was discussed in a previous *Ham Radio* article.<sup>1</sup> The Supercharger uses fewer components than a regular power supply because it doesn't need RF protection. All components are inexpensive and readily available.

FIGURE 1



The basic 723 regulator circuit.  $V_{in}$  is typically 15 to 28 volts to suit your needs.

PHOTO A

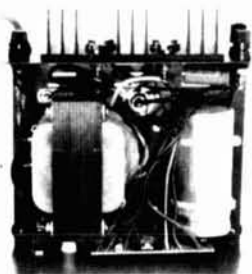


The Supercharger with four of the six outputs located on the front panel. The switches are for high/low charge rates on two of the outputs.



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### SPECIAL FEATURES

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- OUTPUT VOLTAGE: 13.8 VDC  $\pm$  0.05 volts (Internally Adjustable: 11-15 VDC)
- RIPPLE Less than 5mv peak to peak (full load & low line)
- Also available with 220 VAC input voltage



MODEL RS-50A



MODEL RS-50M



MODEL VS-50M

### RM SERIES



MODEL RM-35M

### 19" $\times$ 5 1/4" RACK MOUNT POWER SUPPLIES

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RM-12A	9	12	5 1/4 $\times$ 19 $\times$ 8 1/4	16
RM-35A	25	35	5 1/4 $\times$ 19 $\times$ 12 1/2	38
RM-50A	37	50	5 1/4 $\times$ 19 $\times$ 12 1/2	50
• Separate Volt and Amp Meters				
RM-12M	9	12	5 1/4 $\times$ 19 $\times$ 8 1/4	16
RM-35M	25	35	5 1/4 $\times$ 19 $\times$ 12 1/2	38
RM-50M	37	50	5 1/4 $\times$ 19 $\times$ 12 1/2	50

### RS-A SERIES



MODEL RS-7A

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H $\times$ W $\times$ D	Shipping Wt. (lbs.)
RS-3A	2.5	3	3 $\times$ 4 1/4 $\times$ 5 1/4	4
RS-4A	3	4	3 1/4 $\times$ 6 1/2 $\times$ 9	5
RS-5A	4	5	3 1/2 $\times$ 6 1/4 $\times$ 7 1/4	7
RS-7A	5	7	3 3/4 $\times$ 6 1/2 $\times$ 9	9
RS-7B	5	7	4 $\times$ 7 1/2 $\times$ 10 3/4	10
RS-10A	7.5	10	4 $\times$ 7 1/2 $\times$ 10 3/4	11
RS-12A	9	12	4 1/2 $\times$ 8 $\times$ 9	13
RS-12B	9	12	4 $\times$ 7 1/2 $\times$ 10 3/4	13
RS-20A	16	20	5 $\times$ 9 $\times$ 10 1/2	18
RS-35A	25	35	5 $\times$ 11 $\times$ 11	27
RS-50A	37	50	6 $\times$ 13 3/4 $\times$ 11	46

### RS-M SERIES



MODEL RS-35M

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H $\times$ W $\times$ D	Shipping Wt. (lbs.)
RS-12M	9	12	4 1/2 $\times$ 8 $\times$ 9	13
• Switchable volt and Amp meter				
RS-20M	16	20	5 $\times$ 9 $\times$ 10 1/2	18
• Separate volt and Amp meters				
RS-35M	25	35	5 $\times$ 11 $\times$ 11	27
RS-50M	37	50	6 $\times$ 13 3/4 $\times$ 11	46

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	@13.8VDC	@10VDC	@5VDC			
VS-12M	9	5	2	12	4 1/2 $\times$ 8 $\times$ 9	13
VS-20M	16	9	4	20	5 $\times$ 9 $\times$ 10 1/2	20
VS-35M	25	15	7	35	5 $\times$ 11 $\times$ 11	29
VS-50M	37	22	10	50	6 $\times$ 13 3/4 $\times$ 11	46
• Variable rack mount power supplies						
VRM-35M	25	15	7	35	5 1/4 $\times$ 19 $\times$ 12 1/2	38
VRM-50M	37	22	10	50	5 1/4 $\times$ 19 $\times$ 12 1/2	50

### RS-S SERIES

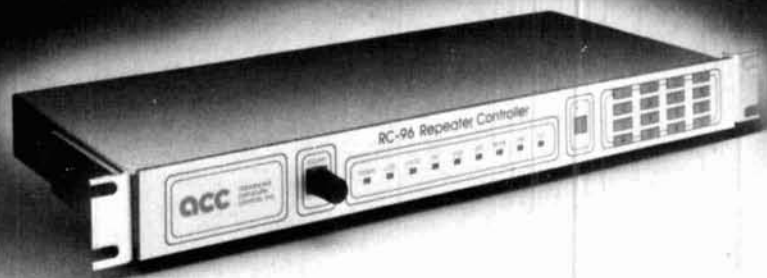


MODEL RS-12S

- Built in speaker

MODEL	Continuous Duty (Amps)	ICS* (Amps)	Size (IN) H $\times$ W $\times$ D	Shipping Wt. (lbs.)
RS-7S	5	7	4 $\times$ 7 1/2 $\times$ 10 3/4	10
RS-10S	7.5	10	4 $\times$ 7 1/2 $\times$ 10 3/4	12
RS-12S	9	12	4 1/2 $\times$ 8 $\times$ 9	13
RS-20S	16	20	5 $\times$ 9 $\times$ 10 1/2	18

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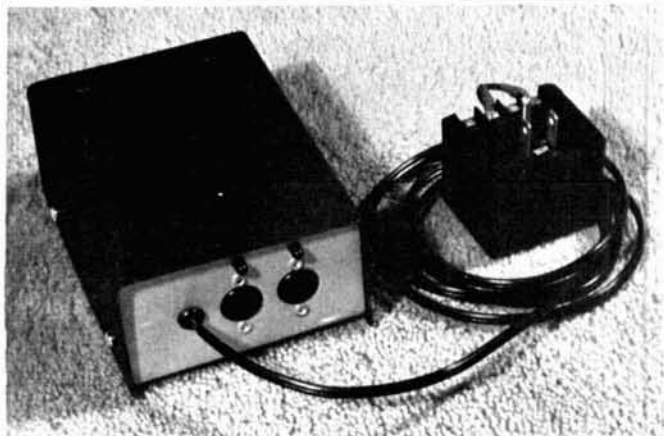
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PHOTO B



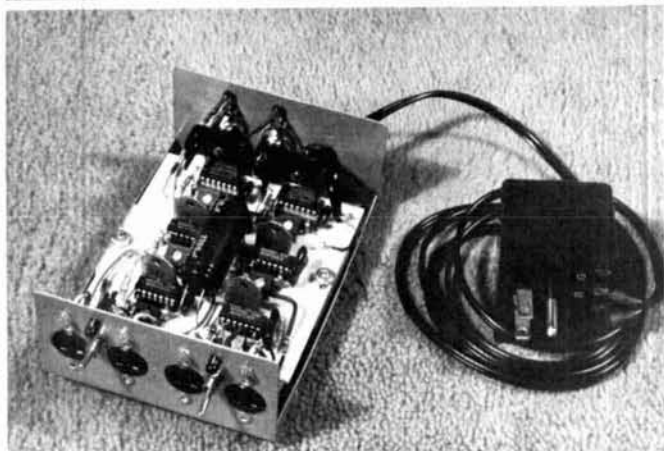
Rear view of the Supercharger showing two output sockets on the rear panel.

PHOTO C



Major Supercharger components and partially completed pc board.

PHOTO D



Completed Supercharger with cover removed. Two of the outputs are located on the rear panel. Note the heat sinks on the two pass transistors at the rear of the pc board.

Current limiting of the device is determined by resistor R4. Use the following formula:

$$\text{Current limiting} = \frac{0.65}{R} \quad (1)$$

A 6.5-ohm resistor for R4 will limit current to 100 mA. R2 is for voltage adjustment and is normally set to a level higher than the maximum voltage required by the device you are charging. Of course the input voltage to the Supercharger must be sufficiently high.

The most popular NiCds are AA cells which are usually 450 mAh (milliamperere hours), and C or D cells which are usually 1.2 AH (ampere hours). The normal charge rate for AA cells is 45 to 50 mA for 14 to 16 hours (150 mA for 4 hours for quick charge cells). The usual charge rate for C or D cells is 80 to 100 mA for 14 to 16 hours.

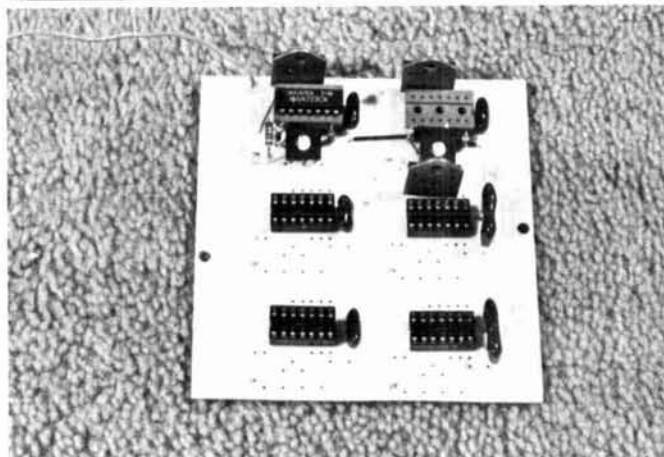
### Design criteria

The Supercharger is designed to provide charge rates of approximately 50 mA, 100 mA, and 150 mA. Lower trickle charge rates of 15 mA are provided for AA cells and 30 mA for C and D cells. Figure 2 shows the R4 values needed to provide three charge levels and two trickle levels. Figure 2A shows a single current output circuit. Figure 2B shows how R4 may be switched to provide high/low (charge/trickle) charge rates. I added LEDs because I like to "see" what's happening. For 15 mA and 30 mA rates, you can use LEDs directly without any current-sharing resistors. They will light only when current is actually flowing. The low charge LED in Figure 2B is really an indicator of switch position, but it doubles as a power indicator for the Supercharger. The LED across R5 lights at high charge levels only when the voltage drop across R5 is great enough for current to flow through this LED. The switches and LEDs were added strictly for personal preference and aren't required.

### Circuit board

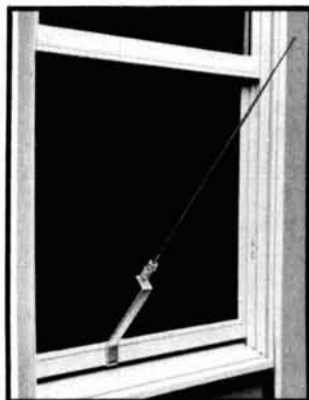
The circuit board for the Supercharger is shown in Figure 3 for eight different charger outputs. My unit uses only

PHOTO E



This Supercharger uses six simple regulator circuits on the same pc board. The black wire at the rear is a jumper to connect the negative supply to both halves of the board.

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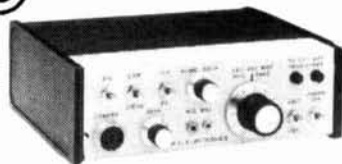
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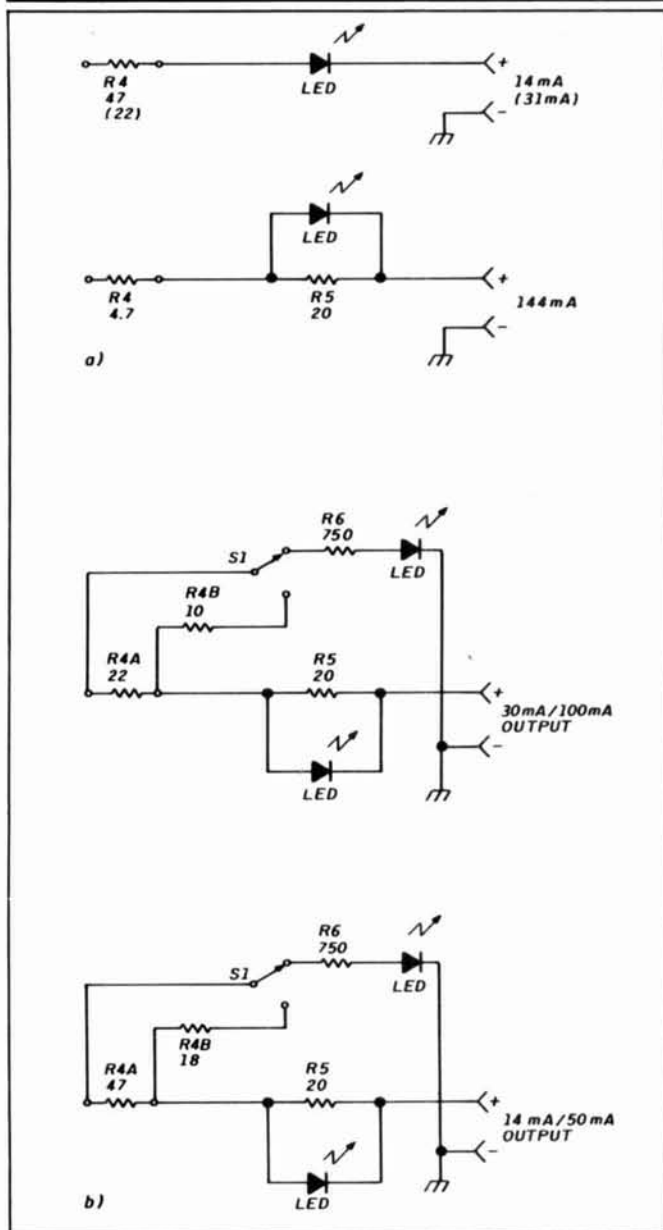
Maryann (WB6YSS)

six outputs because that's what my minibox would accommodate. It's easy to make the pc board using the TEC-200™ film method.<sup>2\*</sup> It took about an hour — not counting a trip to a local copy shop.

### Construction

Once you've made the board, finish assembling the unit and mount it in a suitable enclosure. Component placement for a single charger output is shown in Figure 4. Q1 can be almost any NPN power transistor that will handle the load. The pin configuration of Q1 may vary, but most transistors can be mounted directly on the pc board with proper positioning or perhaps turning them

**FIGURE 2**



**Single current output, (A), LED and/or R5 are optional. High/low selectable output circuit, (B).**

\* The Meadowlake Corporation, 25 Blanchard Drive, PO Box 497, Northport, New York, 11768, (516)757-3385.

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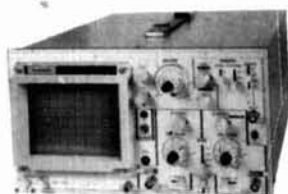
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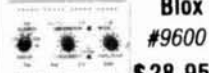
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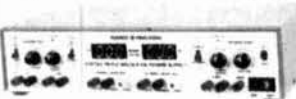
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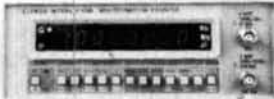
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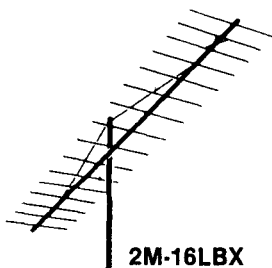
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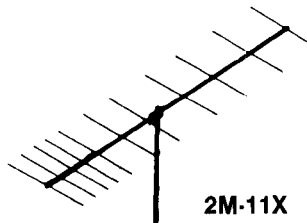
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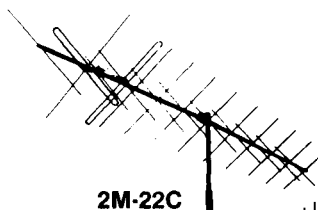
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Gain.....12.5 dBd  
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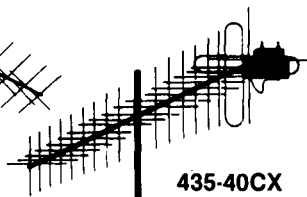
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Gain.....13 dBc  
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435-40CX

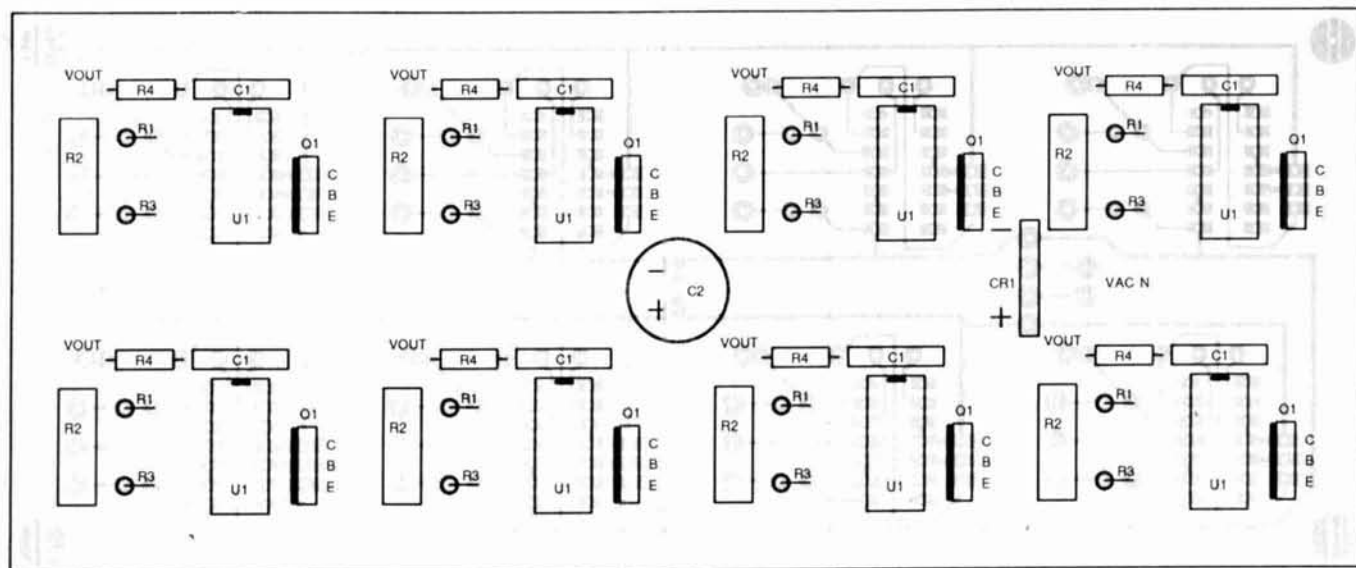
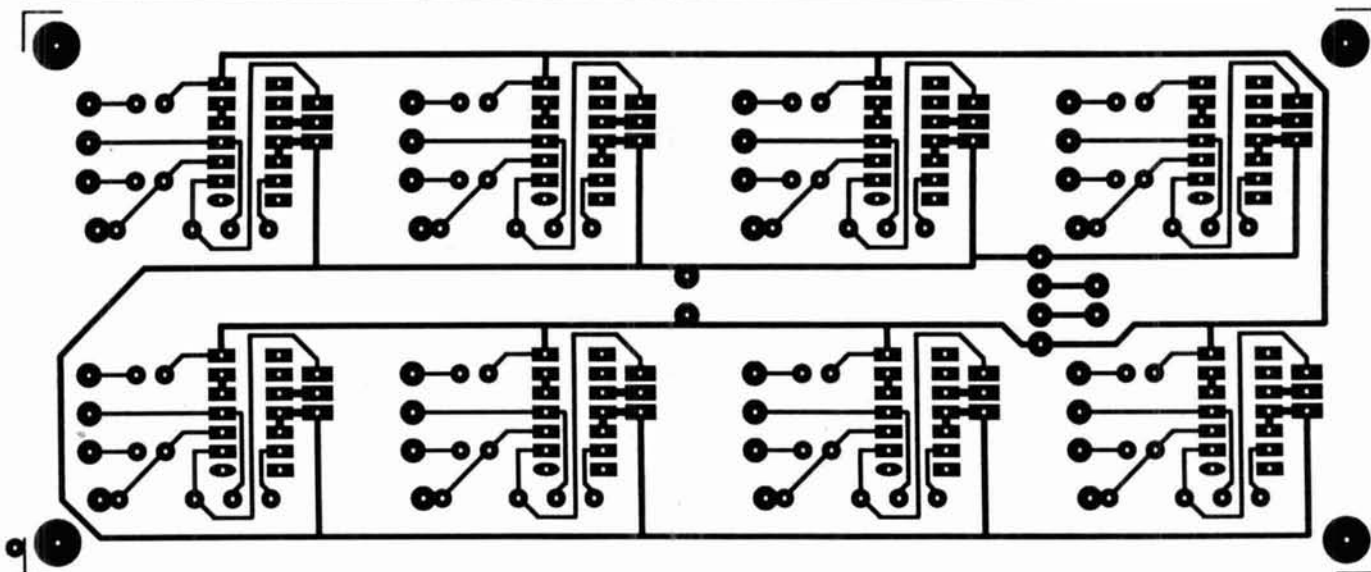
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**FIGURE 3**



**Foil and component sides of the pc board with eight regulator circuits. The board can be cut for the number of circuits desired. CR1 and C2 are mounted on the component side. CR1 may be omitted if Vin is DC.**

180°. On the TIP35 I used, I bent the emitter leg 90°, let it lie flat on the top of the board, and soldered the jumper directly to the leg. You'll have several unused pads on the pc board because it includes the capability for an RF-protected power supply.

Input power to the Supercharger may be AC or DC. I used a 22-volt 0.6-A AC wall transformer, so I added full-wave bridge CR1 and filter capacitor C2 directly to the board. Some wall transformers already supply DC voltage and can be used without CR1 by connecting the DC leads to the appropriate busbars on the pc board. By the way, if you install CR1, you can still use your DC supply without regard to input polarity. You must also place jumpers from positive to positive and negative to negative on each "bank" of four circuits.

## Operation

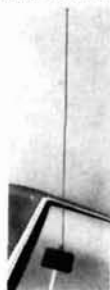
Now power up the unit. My DC supply was about 28 volts (less under load), so I adjusted R2 for 20 volts for all six outputs. I checked the current limit of each regulator by placing an ammeter directly across the output.

Each output will charge 1 to 12 NiCd's easily without any adjustment. Remember, all you care about is the proper current, and that's determined by R4. If you are charging only one NiCd, there will be a large voltage drop across Q1. This power dissipation may require a heat sink on Q1. If you use a full charge rate, don't forget to change to trickle charge after the appropriate charge time by adjusting the switch position or plugging your device into an output of lower current.

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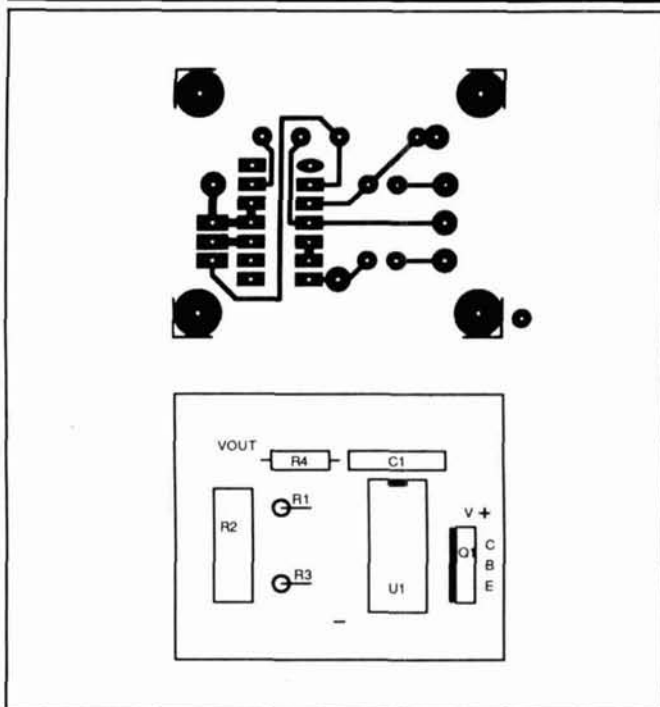
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FIGURE 4



Foil and component sides of pc board with one regulator circuit. The board allows some flexibility for mounting Q1 and R2. R1 and R3 are mounted vertically.

### Automatic fast charge — a bonus

There's one more neat trick you can do with the Super-charger. Because R2 was included and will adjust voltage from about 8.5 to 25 volts, you can set the voltage limit to reduce the charge rate automatically as your NiCds reach full charge.

To determine the proper voltage limit for a particular battery pack (my HT battery, for example), I give it a normal full charge using the charger supplied by the manufacturer. Then I place the battery pack on one of the 150-mA outputs with an ammeter in series. Next, I adjust the voltage using R2, so that the current to the fully charged battery pack is 15 mA (0.03 x 500 mA, or 15 mA for an AA cell).

If I place a discharged HT battery pack on this output, it charges immediately at 150 mA. The charge rate tapers off as the battery becomes charged. This "fast charge" isn't as efficient as a sophisticated circuit using comparators and/or timers, but it sure beats the wall charger that comes with the HT. And, I didn't have to do anything to the Super-charger to get this added benefit. *hr*

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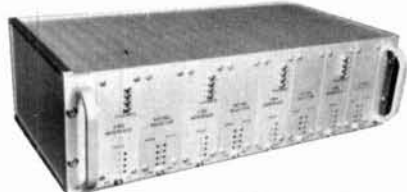
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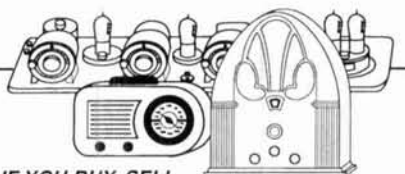
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# EFFECTIVE NOISE TEMPERATURE PART 2

## EQUIVALENT NOISE TEMPERATURE AND NF

### Understanding optimum noise performance

By Michael E. Gruchalla, P.E., 4816 Palo Duro N.E., Albuquerque, New Mexico 87110

In "Effective Noise Temperature, Part 1," I gave an introduction to and background on the concept of effective noise temperature. Part 2 picks up the discussion of the limiting value of source voltage, and goes on to talk about noise figure phenomena and amplifier equivalent noise temperature.

When the source in the small signal example in part 1 is fed to a matched 50-ohm load, the load signal and noise voltages are each  $0.561 \mu\text{V}$ . The power delivered to the load is  $6.29 \times 10^{-15}$  watts. That is precisely the power you'd expect to be available to a matched load from a room temperature resistive source and  $\pi/2$ -MHz noise bandwidth using Equation 1 from part 1.

### Noise power and a matched load

It's important to note that the noise power available to a "matched" load is independent of the source resistance. This is implied by Equation 1. It's a bit difficult to see, because if you look at Equation 5 from part 1 you'll note that changing the source resistance changes the equivalent noise voltage (or current in Equation 6, part 1). However, if you change the source resistance — lower it to reduce thermal noise voltage, for example — the matched load is changed to the same value. You can take the model of Figure 3, part 1 in terms of the general source resistance

and compute the noise power delivered to the load using Equation 5.

$$\begin{aligned} P_L &= E_L^2/R_L \\ &= [(R_L/(R_L+R_s)) (2 \sqrt{k T BW_n R_s})]^2/R_L \\ &= [R_L/(R_L+R_s)]^2 4 k T BW_n (R_s/R_L) \end{aligned}$$

but  $R_L = R_s$  for a matched load. Thus:

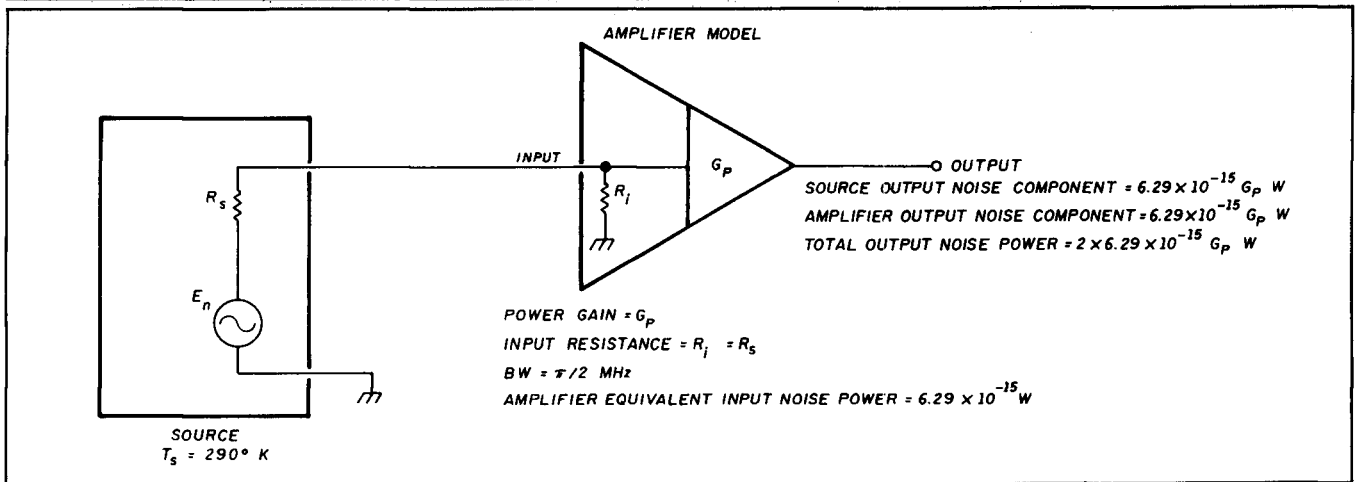
$$P_L = k T BW_n \quad (7)$$

The result in Equation 7 is the same as that given in Equation 1. This is to be expected because you worked forward from Equation 1 to arrive at Equation 5. However, taking the analysis full circle to the starting point should demonstrate that the thermal noise power available at a matched load is independent of the actual resistance, even though the actual equivalent noise voltage and current are functions of the resistance.

### Maximum thermal noise power

The implication of Equation 1 is very important. Because the noise power available at a matched load is independent of the source impedance (resistance and reactance), you may compute the maximum thermal noise power available to a load (an amplifier input, for example) without any information about the amplifier or the system in which it is used. From Equation 1, that power level at room temperature is about  $4 \times 10^{-21}$  watts/Hz of noise bandwidth, or  $-174$  dBm/Hz. This may seem like a very small level, but remember the value is for a "1-Hz" bandwidth. In the preceding example with a  $\pi/2$ -MHz noise bandwidth, the limiting thermal noise power would be  $-112$  dBm. The  $1.12\text{-}\mu\text{V}$  thermal noise voltage of the 50-ohm source resistor with a  $\pi/2$ -MHz noise bandwidth delivered  $0.56 \mu\text{V}$  to a matched load. Consequently, the thermal noise power available at the load from the source resistance is  $6.29 \times 10^{-15}$  watts, or  $-112$  dBm.

FIGURE 1



Amplifier signal-to-noise model.

### Source noise and amplifier noise

It may seem that the noise performance (S/N) could be improved by providing a less than optimum impedance match. It's true that in such a case less source noise would be available at the amplifier input. However, because the source resistance is the same for both the noise and signal components, less signal will also be coupled. For any given signal, the source signal-to-noise ratio remains constant for any matching condition. Because the amplifier to which this source is attached is very likely to contribute some noise, any reduction in the input signal component tends to cause the amplifier noise to be more significant and suggests a degradation in the noise performance of the system; that is, the output signal-to-noise ratio would be degraded. But for any specific amplifier and nonzero source level, there's a source impedance that will result in the best signal-to-noise ratio. This is the noise match impedance, and it's totally unrelated to the optimum power transfer impedance.<sup>1,3</sup> It is a function only of the amplifier noise characteristics. This concept is discussed in detail in **References 1 and 3**.

### Noise figure

The noise figure is defined as the ratio of the total output noise power of a system to the output noise power due to the source alone, expressed in decibels. You can read **Reference 3** if you'd like a detailed description.

$$NF = 10 \log \left[ \frac{\text{Total Output Noise Power}}{\text{Output Noise Power Due to the Source}} \right] \quad (8)$$

Noise analyses are generally referred to the output of the systems under consideration. The system output is typically the most convenient point to make signal measurements. Also, in many cases, the various signal quantities of interest aren't directly accessible. For example, the equivalent input noise voltage of an amplifier can't be measured directly. It must be computed from output noise measurements.

Consider the amplifier in **Figure 1** with a power gain  $G_p$ , signal bandwidth of 1 MHz, equal source and input

resistances, and a room temperature source. The noise power at the amplifier input due to the source is  $6.29 \times 10^{-15}$  watts. Also, let the amplifier have an "equivalent input noise power" equal to that delivered to the input by the source resistance,  $6.29 \times 10^{-15}$  watts (unity power signal-to-noise ratio). The output noise power due to the source is  $6.29 \times 10^{-15}$  watts  $\times G_p$ . The total output noise power is equal to the sum of the source and amplifier noise power contributions. Because the amplifier equivalent input noise was defined to be equal to the source noise, the total output noise power is twice the source noise contribution. This means the noise figure is  $10 \log (2)$ , or 3 dB.

### Noise figure as a function of temperature

The preceding seems like a reasonably good specification for the noise performance of an amplifier. It is perhaps the most common method of specifying the noise of various systems. However, it does have at least one serious shortcoming: a specific noise figure value is valid only at a *specific temperature*. For a specified noise figure value to apply, the source must be at the same temperature in the application as it was for the original specification. To demonstrate this, I'll cool the source resistor in **Figure 1** to a temperature of 96.7°K. The noise figure given by **Equation 8** will then be 6 dB. The cooler resistor contributes less noise. So the amplifier noise power, although the same in both cases, is a factor of 3 higher than the source contribution when the source is at 96.7°K, while it is equal in the 290°K case. The total output noise is actually reduced with the colder source. For any given signal, the signal-to-noise ratio is increased. But the percentage of total output noise contributed by the amplifier in the cold case is higher than it is for the room temperature case. This results in a poorer noise figure, even though the signal-to-noise ratio for any specific signal is improved (see **Reference 3** for a more detailed discussion of NF versus S/N). In order to effectively use a noise figure specification, you must know the temperature at which the noise figure was specified. Of course, this isn't particularly useful if you wish to use the amplifier for sources of a different temperature, or perhaps if you don't precisely know the source temperature.

## Equivalent noise temperature

The noise characteristics of an amplifier may be specified in an alternative manner. From **Equation 1**, the maximum noise power available at the input to a system is a function of only the source temperature and the noise bandwidth (and of course Boltzmann's constant). This maximum available noise power occurs only for a power-matched condition of the source and amplifier input. For any real system, a value of temperature for the matched source may be computed by rearranging **Equation 1** so the noise contribution due to the source at some point in the system of interest (usually the output as discussed above) is the same as that contribution at that same point from the noisy amplifier itself.

The equivalent noise temperature of the amplifier is the temperature to which a power-matched source resistance must be set to provide a source output noise power component equal to the amplifier component of output noise power.

In the amplifier example with the room temperature (290°K) source, the source noise contribution and amplifier noise contribution are equal. Here, the source must be at 290°K to provide an output noise component equal to that of the amplifier. That amplifier is then a 290°K amplifier. If this amplifier were used with the 96.7°K source, it would still be a 290°K amplifier. It's important to remember that equivalent noise temperature is a property of the amplifier (or other system characterized) — somewhat like gain — and is independent of the application.

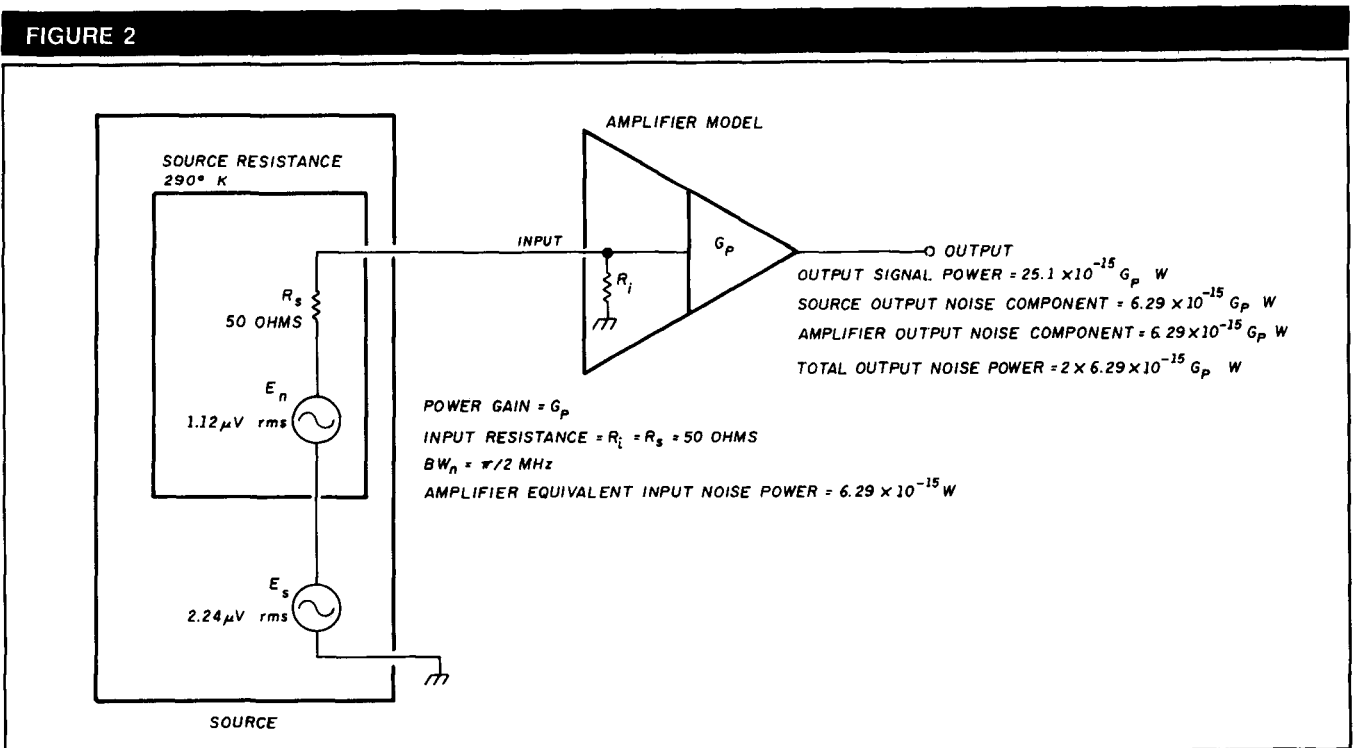
## Ideal and real noise applications

The noise temperature specification has a shortcoming. It is a specification of noise performance when the source

is power matched to the amplifier and may be thought of as a type of ideal specification. It usually doesn't represent the performance provided in a real application. If an unmatched source is used with an amplifier of some specified noise temperature, the output signal-to-noise ratio will be different from that obtained with ideal matching (it could be better or poorer). However, the noise temperature specified for the amplifier would still be correct because it's based on performance in a specific configuration. Further, because the noise temperature is based on an input power-matched condition, it provides no information about the optimum performance that may be obtained in a noise-matched input. A similar noise temperature versus signal-to-noise ratio comparison could be made as presented in **Reference 3** for noise figure versus signal-to-noise ratio. Just because an amplifier has a very low noise temperature doesn't mean it will provide best signal-to-noise ratio in a specific application. It's very likely that a higher noise temperature amplifier with an input well noise matched<sup>3</sup> to the source will provide a much better signal-to-noise ratio than an amplifier of much lower noise temperature with a poorly noise-matched input. The optimum noise-matched source resistance is given by the ratio of the equivalent input noise voltage and the equivalent input noise current. See **References 1 and 3** for a thorough review of noise matching.

## Noise-matching example

• **290°K amplifier.** Consider the amplifier in **Figure 2**. It's the same as that of **Figure 1** with a signal added. The amplifier equivalent noise temperature is 290°K, input resistance is 50 ohms, signal bandwidth is 1 MHz, and power gain is  $G_p$ . For convenience, I chose  $2 \times 1.12 \mu\text{V rms}$  as the input source signal. This is twice the source thermal noise level. The signal at the amplifier input is then  $1.12 \mu\text{V rms}$  and the output



290°K amplifier model.

put signal power  $25.1 \times 10^{-15}$  Gp watts. The noise voltage available at the amplifier input from the 290°K source is  $0.561 \mu\text{V}$ , an output noise power due to the source of  $6.29 \times 10^{-15}$  watts. Because the amplifier has a 290°K noise temperature, its equivalent input noise power is the same as that of the 290°K source, or  $6.29 \times 10^{-15}$  watts. As a result, the total output noise power is  $12.58 \times 10^{-15}$  Gp watts. This means the power signal-to-noise ratio is 2, or 3 dB.

• **145°K amplifier.** With this same source, I'll try another amplifier with a noise temperature of 145°K. This is a factor of 2 lower than the 290°K unit, but with a 10-ohm input resistance — a factor of 5 lower than the matched case. I chose these values for convenience of calculation; they aren't intended to represent any realistic application. However, the 145° value is a modest specification, and the 10-ohm value of input resistance isn't too unreasonable. An NE13783 low noise FET exhibits about a 10-ohm resistive input impedance at 12 GHz. These values are actually quite realistic.

This amplifier is shown in **Figure 3**. Because this is a mismatched case, you need additional information about the amplifier to make truly accurate computations. The noise voltage and current sources at the amplifier input are the "equivalent input noise sources."<sup>1</sup> The values shown give an optimum noise match and 145°K noise temperature at the specified 10-ohm source resistance. There's a family of equivalent input voltage and current source values that will provide a 145°K noise temperature. In a real application of computing noise performance, the equivalent sources would be accurately measured. For this example, the values of **Figure 3** are the defined amplifier characteristics.

• **Noise temperature verification.** First I'll verify that the amplifier is a 145°K unit. The input noise power due to the two amplifier noise sources alone when attached to a matched 10-ohm noiseless (zero degree) source is  $3.14 \times 10^{-15}$  watts, and the output noise power is  $3.14 \times 10^{-15}$  Gp watts. According to **Equation 1**, the temperature to

which a source resistance must be raised to deliver that thermal noise power to a matched load with a  $\pi/2$ -MHz noise bandwidth is 145°K. The amplifier is then indeed a 145°K unit.

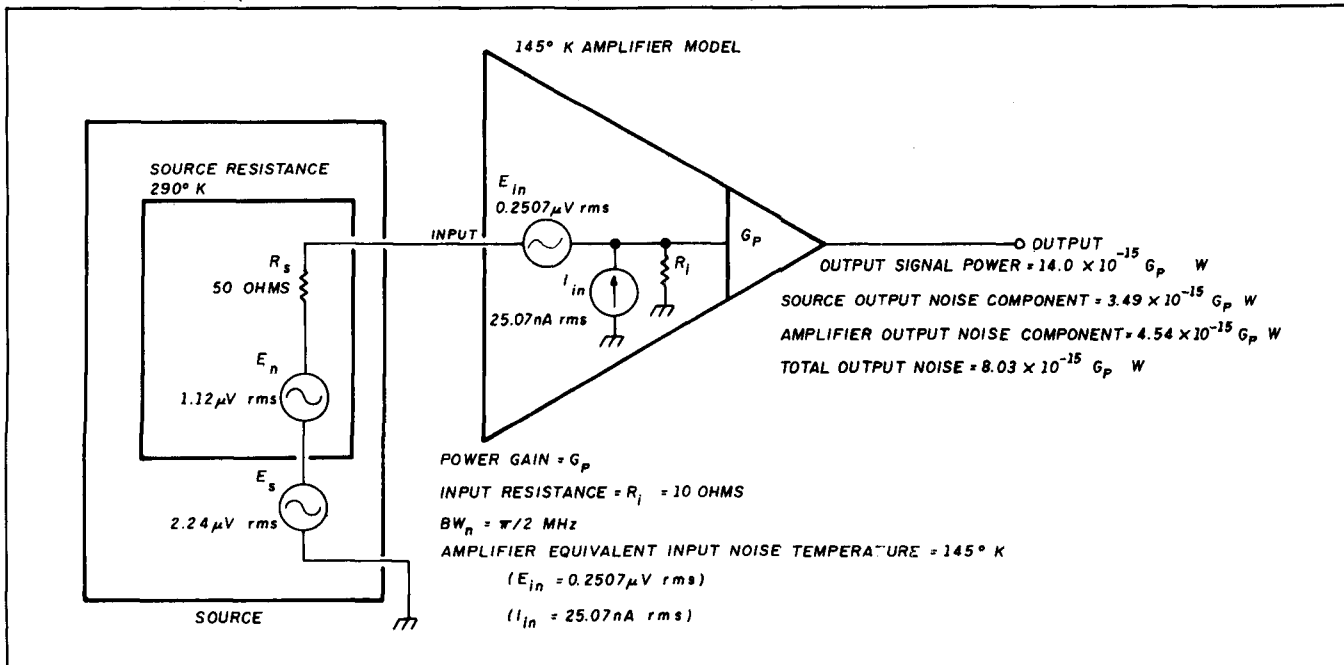
The noise power at the amplifier input due to the 290°K, 50-ohm source and the amplifier equivalent noise sources in **Figure 3** is  $8.03 \times 10^{-15}$  watts. This yields a total output noise power of  $8.03 \times 10^{-15}$  Gp watts. The input signal voltage is  $0.374 \mu\text{V}$  which produces an output signal power of  $14.0 \times 10^{-15}$  Gp watts. The power signal-to-noise ratio is then 1.74, or 2.4 dB.

• **Analysis.** Substituting a lower noise amplifier in the system with the 50-ohm source resulted in a poorer signal-to-noise ratio. But what would happen if you had a source with a 10-ohm source resistance and the 145°K amplifier? This is the optimum "noise-matched" resistance for the amplifier in **Figure 3**. (It's also the optimum power match in this case, but that isn't significant.<sup>3</sup>) This impedance transformation may be very conveniently and realistically accomplished using a transformer with a 2.24:1 turns ratio. By using an ideal transformer, you maintain the source signal power constant and can easily compare various power signal-to-noise ratio results. The transformed source temperature remains 290°K. The amplifier noise temperature is still 145°K because that specification is independent of application. In this case the input signal power will be  $25.1 \times 10^{-15}$  watts and the output signal  $25.1 \times 10^{-15}$  Gp watts. The total output noise power from the 10-ohm, 290°K source and the amplifier noise sources will be  $9.43 \times 10^{-15}$  Gp watts. That results in an output power signal-to-noise ratio of 2.66:1, or 4.3 dB.

## All noise parameters must be recognized

I started with a 290°K amplifier with a 50-ohm input resistance and a 290°K, 50-ohm source and obtained a 3-dB signal-to-noise ratio with a  $2.24\text{-}\mu\text{V}$  source signal voltage.

FIGURE 3



145°K amplifier model.



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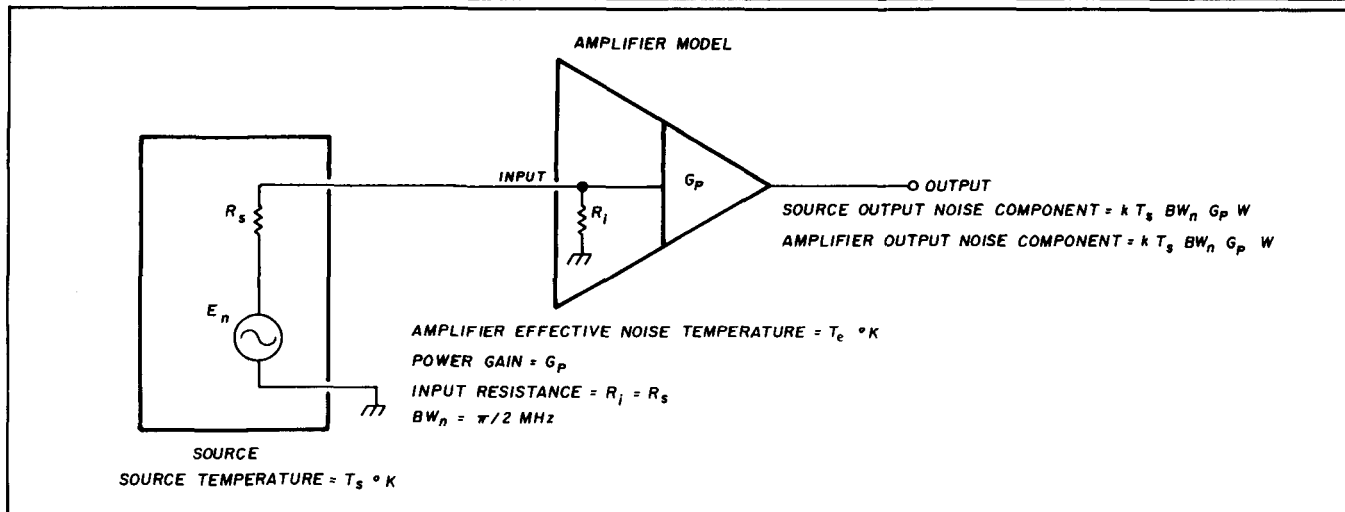
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FIGURE 4



Model for comparing noise figure and effective noise temperature.

I then substituted a lower noise 145°K amplifier with the same signal source and obtained a 2.4-dB signal-to-noise ratio. The lower temperature and lower noise amplifier provided a 0.6 dB poorer signal-to-noise ratio than the higher noise 290°K amplifier with the 50-ohm room temperature source. Then I transformed the 50-ohm, 290°K source to a 10-ohm optimum noise-matched value, still at 290 °K. With the same 145°K amplifier that provided the 2.4-dB signal-to-noise ratio with the 50-ohm source, I then obtained a 4.3-dB signal-to-noise ratio. So this 145°K amplifier with a fixed source power provided a 2.4-dB signal-to-noise ratio with one source resistance and a 4.3-dB value with another. But the noise temperature was constant. Can this be correct? Is there an error here?

The calculations are correct, and indeed this result can easily occur in practice. Although the higher noise temperature amplifier generally exhibits higher noise than the lower temperature unit, it provides a better noise match to the 50-ohm source than did the specified 145°K unit. This gives a better signal-to-noise ratio for any given signal. In the final example, the 10-ohm source provides an optimum noise match resulting in the best signal-to-noise obtainable with the particular amplifier being modeled. What's important here is that the lower noise temperature amplifier has the capability to provide the better noise performance. But to actually obtain improved performance, all of the noise processes must be well understood and the various noise parameters used correctly.

### Importance of understanding noise parameters

In practice you rarely know the exact resistances involved. You have to ask: What is the actual source resistance of an antenna? Is it the radiation resistance? The element resistance? The connecting transmission line resistance? Or is it a combination of all of these? What is the effective temperature of the source(s)? Further, what is the actual input resistance of a low noise amplifier (LNA)? Worse yet, does the LNA even come close to providing a good noise match to your source? These are all very difficult questions to

answer. Careful measurement of the noise parameters must be completed before you can accomplish any true optimization. It's actually possible to replace one LNA with a lower noise temperature unit and achieve a poorer signal-to-noise ratio. Those of you who have experimented with various "inexpensive" LNAs may have stumbled on this paradox. Because these amplifiers are manufactured more for low cost than consistency, they tend to exhibit considerable variation in performance parameters from unit to unit. Even when substituting two identical models, you may see a considerable difference in noise. Of course, a noisier unit may also be defective, or a quieter one could be a premium low noise unit. An understanding of the actual noise processes is critical for successfully optimizing system noise performance.

### Comparing noise temperature and NF

As a final thought, it might be useful to compare noise temperature and noise figure. Both of these specifications are measures of device noise, so it should be possible to compare them effectively. To do this, use Equation 8 and the amplifier model in Figure 4. This amplifier configuration is similar to those shown earlier, but has a general source temperature  $T_s$  and an amplifier equivalent temperature  $T_e$ . Because the configuration in Figure 4 offers a matched load to the source, you know the noise power delivered to the amplifier input from Equation 1. The output noise power due to the source alone,  $P_s$ , is then given by Equation 9.

$$\text{source output noise power} = P_s = k T_s BW_n G_p \quad (9)$$

Now when the amplifier is attached to a power-matched source at a temperature equal to the effective temperature of the amplifier, the source and amplifier contribute equal noise components to the total output noise. This is essentially the definition of effective noise temperature. The component of the amplifier output noise,  $P_a$ , is simply equal to the noise that would be output if the amplifier were noiseless and the source were at a temperature  $T_e$ . By the definition of effective temperature,  $T_e$  is that temperature to



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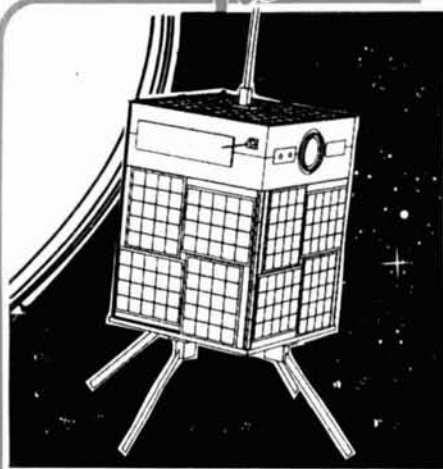
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which you must raise the source if the amplifier were noiseless to produce an output noise equal to that of the actual noisy amplifier with a noiseless source. Once again, the input power is given by Equation 1 and the corresponding amplifier output noise power contribution by Equation 10.

$$\text{amplifier output noise power} = k T_e BW_n G_p \quad (10)$$

By combining Equations 8, 9, and 10, you can express the noise figure in terms of the source temperature and the amplifier effective temperature.

$$\begin{aligned} NF &= 10 \log \left[ \frac{P_s + P_a}{P_s} \right] \\ &= 10 \log \left[ \frac{(k T_s BW_n G_p) + (k T_e BW_n G_p)}{(k T_s BW_n G_p)} \right] \\ &= 10 \log \frac{T_s + T_e}{T_s} \end{aligned}$$

$$NF = 10 \log [1 + T_e/T_s] \quad (11)$$

Equation 11 then lets you compute the noise figure of an amplifier from its effective noise temperature. For example, if you have a room temperature source of 290°K ( $T_s = 290^\circ\text{K}$ ), a 290°K amplifier ( $T_e = 290^\circ\text{K}$ ) will exhibit a 3-dB noise figure as expected. You may also compute the effective noise temperature from the noise figure by solving Equation 11 for  $T_e$ . That result is shown in Equation 12.

$$T_e = T_s (10^{NF/10} - 1) \quad (12)$$

## Closing remarks

Hopefully, all this has shown you just what the concept of effective noise temperature means and how it was derived. Unlike noise figure, the noise temperature is a device parameter (like gain) and is independent of the application of the device. On the other hand, noise figure is a comparison of the output noise power of a system due to the source alone — a real source, any source, matched or not — to the total output noise power of the system. So, the noise figure is a type of "practical" noise specification showing the performance of a real system, while the noise temperature is a type of standard specification defined under very specific conditions.

Both equivalent noise temperature and noise figure are useful parameters, but both have shortcomings. The successful use of any parameter depends upon a thorough understanding of that parameter. Obtaining optimum noise performance depends greatly on your understanding of the noise processes and careful application of the optimizing principles discussed in this article and the references. **hr**

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2. S.P. Parker, *McGraw-Hill Dictionary of Scientific and Technical Terms*, Third Edition, McGraw-Hill, New York, 1984.
3. M.E. Gruchalla, "Understanding Noise Figure," *Ham Radio*, April 1987, page 89.

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1. Joe Carr, K4IPV, "Practically Speaking: Noise, Signals, and Amplifiers," *Ham Radio*, February 1988, page 77.

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# Ham Notebook

## An RF Current Loop

Here's a handy device for tracking down RF current in your antenna. Knowing your antenna means knowing where RF current flows. Does your



feedline radiate? It shouldn't, even if it's made of open wire line. How about the phone lines or guy wires? These and other objects could be robbing you of RF or distorting your radiation pattern. The circuit shown in **Figure 1** and pictured in **Photo A** will give you a true representation of your antenna by detecting RF current.

**PHOTO A**



Completed RF tracker.

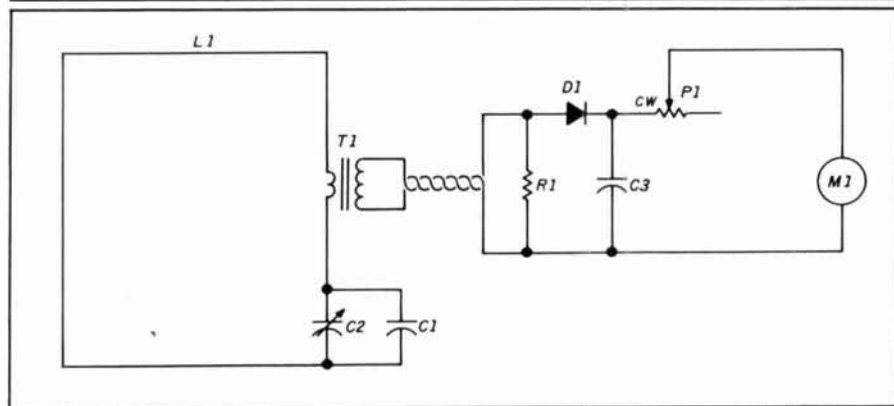
**TABLE 1**

Loop components versus frequency of operation.

Frequency, MHz	*Wire loop L1, inches	C1, pF	C2, pF
16 - 30	15	none	95 - 420
9 - 16	26	none	95 - 420
7 - 8	26	560	95 - 420
3.7 - 4.0	26	2200	95 - 420

\* Cut length of copper-weld wire

**FIGURE 1**



RF current loop.

## Operation

Load the antenna with about 50 watts. Run the loop along the length of the suspected object while observing meter deflection. Maximum meter indication occurs when the wire edge of the loop is parallel with the direction of current. A meter zero (null) will occur at angles perpendicular to current flow.

Remember that current peaks repeat every half wavelength, so that maximum meter indication may be one-quarter wavelength from where you initially probed. There will be little or no indication at voltage maxima.

## Calibration

Carefully tune the loop using a grid-dip meter. Adjust C2 until resonance is indicated. You may want to monitor the grid-dip frequency with your station receiver to verify meter accuracy.

An alternative tuning method would be to hold the loop near the antenna and adjust C2 for maximum. The peak will be sharp, so adjust carefully.

The key to the loop's performance is its relatively high Q afforded by toroidal transformer T1. The loop should be operated within about 150 kHz of resonance for best sensitivity and results.

## Construction

Shape a piece of no. 14 copper-weld wire into a square and thread it

## PARTS LIST

- C1 Silver mica. See Table 1 for value.
- C2 95 to 420-pF trimmer (Radio Shack)
- C3 Ceramic capacitor, 0.1- $\mu$ F, 100 volt
- CR1 Diode, 1N914
- L1 Wire loop. See Table 1 for length.
- M1 Meter, 0 to 1 mA
- R1 Resistor, 56-ohm carbon composition 5 percent, 1/4 watt
- R2 Potentiometer, 10 k
- T1 T-50-2 (Amidon), wound with 15 turns no. 26 AWG — leave a 7" pigtail\*

Limited range of C2 and tolerance of parts may require up to a 10-percent change of C1 value.

\* Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607

through transformer T1. See Table 1 for loop length. Secure the loop to one end of a 5/16 by 24-inch dowel. Be sure to leave about a 1-inch gap in the loop to mount C2. Twist the leads of T1 and run them down the dowel about 6 inches.

Mount the detector components consisting of R1, CR1, and C3 to the dowel and wrap them with electrical tape. Attach the wires from C3 to the meter and sensitivity pot located near the handle.

### Final remarks

I have discussed a simple means of detecting antenna currents with the aid of the RF current loop. Now that the currents can be identified, they can be contained. Past *Ham Radio* articles and the *ARRL Antenna Book* contain some excellent suggestions to help reduce unwanted radiation and pickup. It should now be easy to evaluate the best solution for your antenna system. Let's go for top performance and put that RF up where it belongs!

**Tom Rehm, K9PIQ**

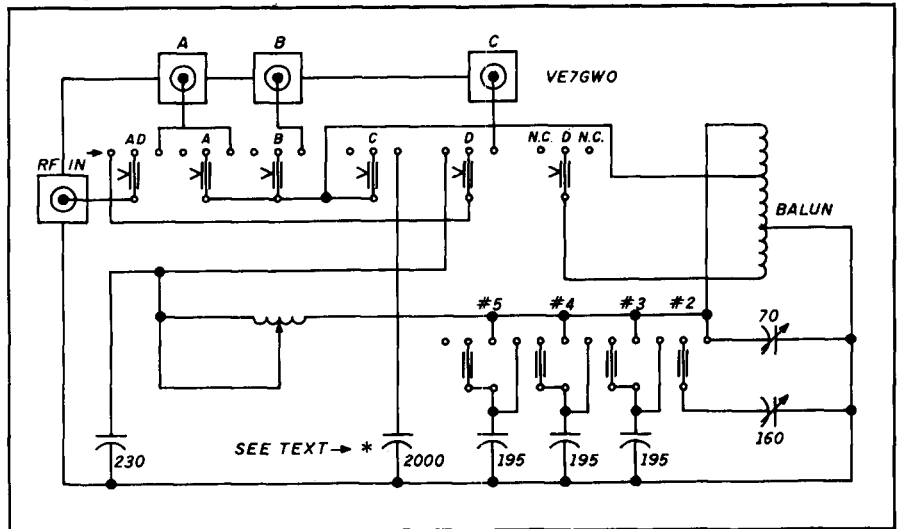
## Updating The Viking MB-VA Antenna Tuner

After purchasing and connecting a Viking antenna tuner MB-VA, I was dis-

appointed because it would not tune my 160-meter antenna. Here are two solutions to the problem.

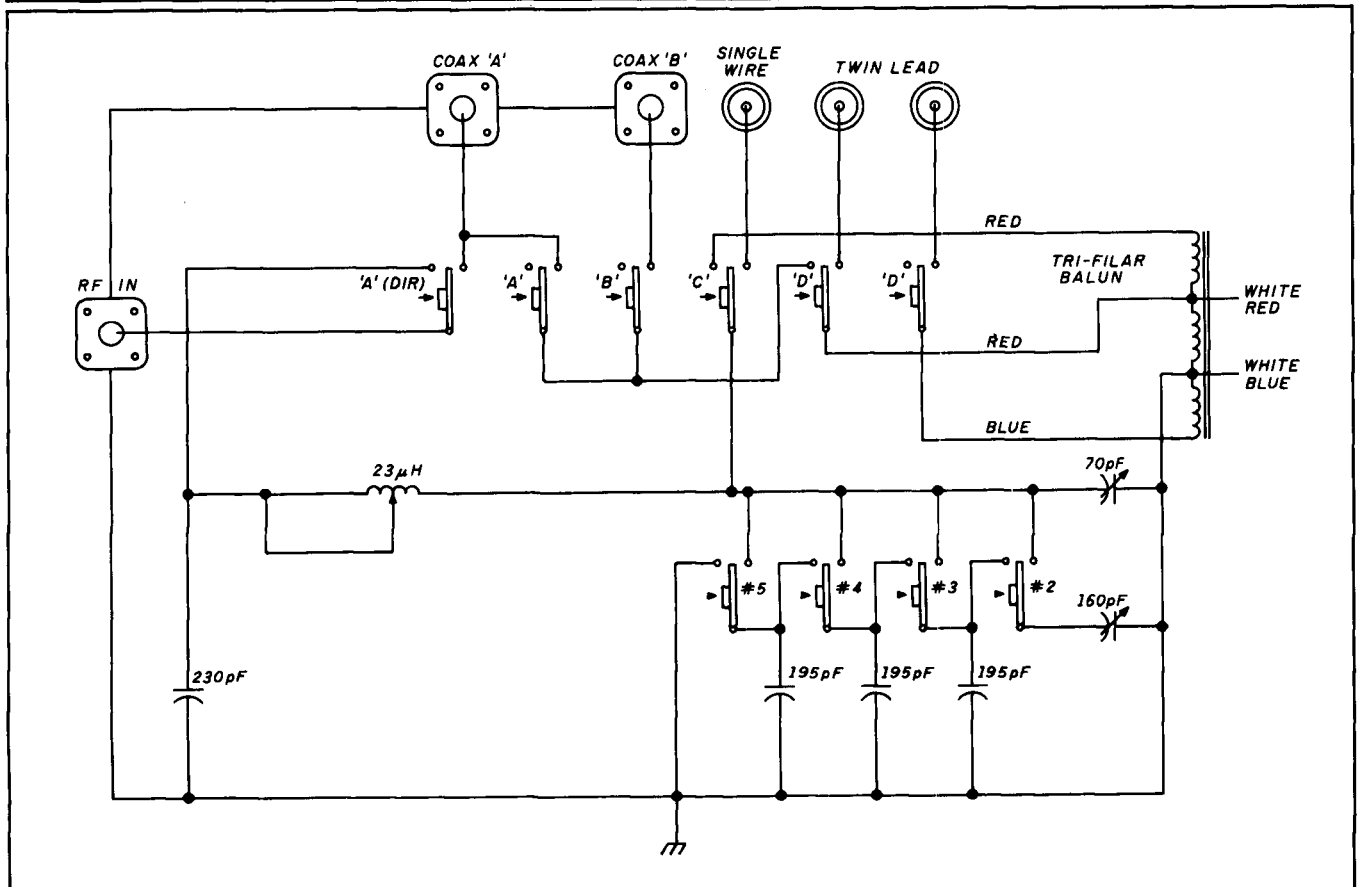
I could leave the antenna tuner wiring the way it was. Then, for 160-meter operation, I could mount a 2000-pF

FIGURE 1



Schematic showing changes to the Viking MB-VA antenna tuner.

FIGURE 2



Manufacturer's diagram of the Viking MB-VA tuner.

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P432VDG	420-450	<0.5	16	+12	GaAsFET	\$79.95
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A further change lets me use a dummy load through connector C. I disengaged the connections from the insulators of the balance line, then removed the single insulator and replaced it with coax connector C.

Note that there is an error in the manufacturer's diagram. The bus connecting A and B does not connect to C (Figure 2).

I hope my suggestions will help Viking tuner owners make the most out of this well-made piece of ham gear.

G.W.T. Oliver, VE7GWO

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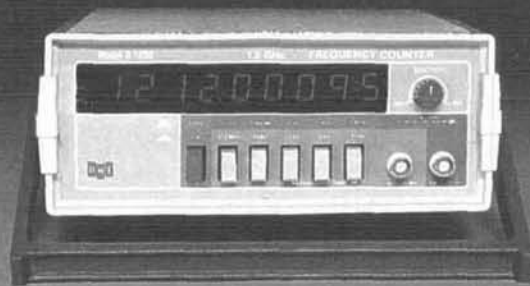
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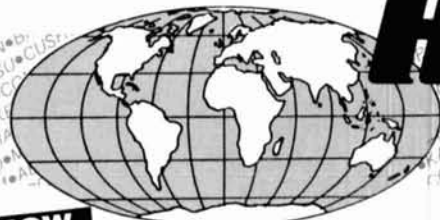
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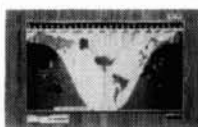
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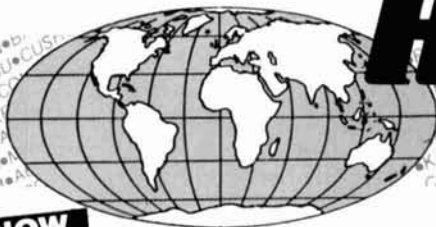
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# Ham Radio Techniques

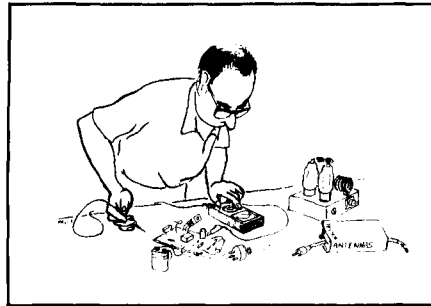
Bill Orr, W6SAI

## 160-METER ANTENNA PROBLEMS AND SOLUTIONS

The quarter-wave Marconi working against ground is a popular and inexpensive antenna for 160 meters. A lot of newcomers to the band favor this simple antenna because it's easy to put up, it isn't too big, and it works.

I erected such an antenna a few years ago. I had an enjoyable time and worked a lot of stations on 160, but the signal reports I received weren't very ego building. Worst of all, many of the local 160-meter crowd were working DX I couldn't even hear! That was a bad sign. It meant that something had to be done about the antenna. I couldn't go to a vertical, and the position of the house on the lot precluded putting more wire up in the air. I had to make do with what I had.

The Marconi installation is shown in **Figure 1**. It would have been nice to get the flat top higher in the air, but that was impossible. Because I couldn't use a bigger antenna, I had to look elsewhere to improve my signal. Knowing that the transmitter power had to flow through the ground connection, this seemed a logical place to make an improvement in my signal. The ground consisted of the copper water system in the house plus one ground rod. Discussions with DXers on the band quickly convinced me that my ground wasn't as good as I'd hoped it would be. A lot of RF was being wasted in ground resistance. To monitor improvements, if any, I placed an RF ammeter in series with the antenna. With a power output of 80 watts, I logged 1.27-A antenna current. Ohm's law showed my antenna feedpoint resistance was about 49.6 ohms — a good match to my transceiver, even if DX performance was unimpressive.



### Improving the ground connection

I suspected that a lot of my output power wasn't going into the ground connection. Where else could it go? Perhaps it was going down the line cord and into the house wiring. Acting on this supposition, I wrapped the line cord around a ferrite rod and noticed the antenna current had now increased to 1.65 A. The feedpoint resistance of the antenna had dropped to 29.4 ohms. That indicated less ground loss. But now it was more difficult to match the antenna to the transceiver. I needed an antenna matching unit to achieve a 50-ohm interface.

My next step was to add two quarter-wave radials to the system. These wires ran about a foot above the ground and wound in and out through the shrubbery in the yard. It was the best I could do. Unfortunately, there was no room to add additional radials. I had to be content with what I had. The radials

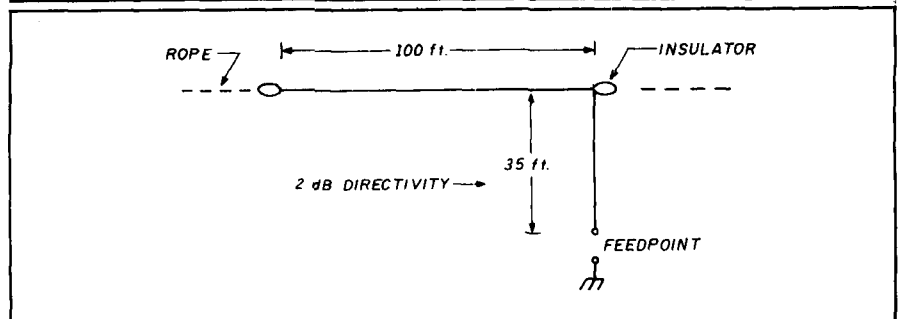
brought the antenna current up to 1.82 A. This was another step in the right direction. Now the computed feedpoint resistance of the antenna was about 24.2 ohms.

There seemed to be a modest improvement in the antenna. I now found I could work some DX. Mine wasn't the loudest signal on the band, but the little antenna provided a lot of fun when the DX guns were occupied elsewhere. However, a nagging thought remained in the back of my mind. How efficient was the antenna? Had I really conquered the ground loss problem?

### Computer analysis of the antenna

I didn't do much more with the antenna installation, and during the warm summer months I lost interest in 160-meter operation. But last fall I decided to get back on the band. Now I was able to analyze the antenna with the new K6ST1 computer program discussed in my last column.<sup>1</sup> The analysis revealed that the true feedpoint resistance of my antenna over typical soil in this location was only 7.8 ohms! Because my measurement of antenna current indicated a feedpoint resistance of about 24.2 ohms, the inescapable

FIGURE 1



**“Old Faithful” 160-meter Marconi antenna is full of surprises that will fool the unwary user. Antenna is self-resonant at 1.85 MHz.**

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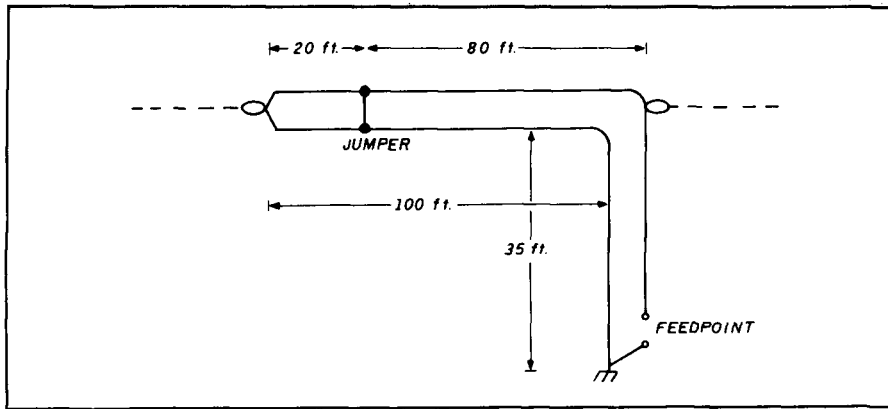
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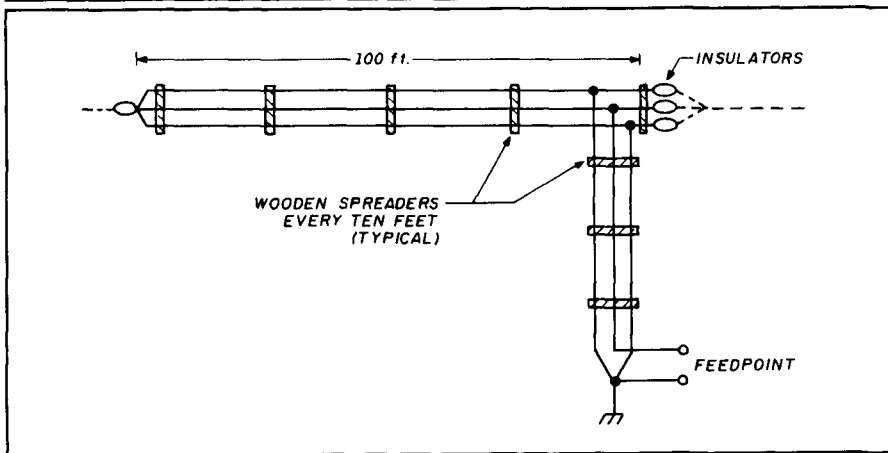
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**FIGURE 2**



"Twin-lead" Marconi antenna. TV-type 300-ohm line is shorted 20 feet from end to account for velocity factor of line.

**FIGURE 3**



Three-wire Marconi provides high value of feedpoint resistance. If outer wires had half the diameter of the inner fed wire, the impedance step up would have been 9:1.

conclusion was that the difference between the two figures (16.4 ohms) represented *ground loss*. My antenna efficiency was only about 32 percent! That meant that out of 80 watts, I was radiating only about 25 watts. The rest of my power (55 watts) was just warming the ground.

This also meant that I suffered about 4-dB signal loss in reception. No wonder I couldn't hear some of the weak DX on the band!

### The solution: the folded Marconi antenna

In early spring I decided to change the single wire Marconi antenna to a folded system using two parallel wires (Figure 2). One wire was fed and the other returned to the ground connection. This provided an impedance step-up of four, and allowed an improved value of radiation resistance of 7.8 ×

4, or 31.2 ohms. The ground resistance remained the same value as before (16.4 ohms), indicating that antenna efficiency was now about 66 percent. I had picked up 3 dB in transmitted power and had gained 3 dB in signal reception! Not a bad improvement for substituting 300-ohm ribbon line for the no. 14 wire in the antenna.

My final idea was to go to a three-wire folded antenna, which would provide an impedance step-up of about 11:1 (Figure 3). The antenna feedpoint resistance would then be 7.8 × 11, or 85.8 ohms. With 16.4 ohms ground resistance (which I didn't seem to be able to eliminate), the overall antenna efficiency rose to 84 percent! The small series of improvements gave me nearly 4-dB boost in transmission and reception at little cost.\*

\*That's an increase in power ratio of 2.51:1. Ed.

As I had no three-wire conductor on hand, I made one out of three no. 14 wires spaced 1 inch apart with a number of 4 inch long wooden spreaders. The assembly was a rat's nest on the ground but it straightened out when I got it up in the air and under tension.

A final run of the computer program showed that the Marconi exhibited about 3-dB directivity in the direction of feed, as Marconi had predicted long ago. In addition, the computer showed that the greater the length of the vertical portion of the Marconi, as compared with the horizontal section, the greater the feedpoint resistance. The limit, of course, is when the whole antenna is vertical. A single conductor has a feedpoint resistance of about 37 ohms (Figure 4).

How were my operating results? Much, much improved over the original design. At times, I even had DX stations answer my CQ. WOW!

### Running the MN antenna program

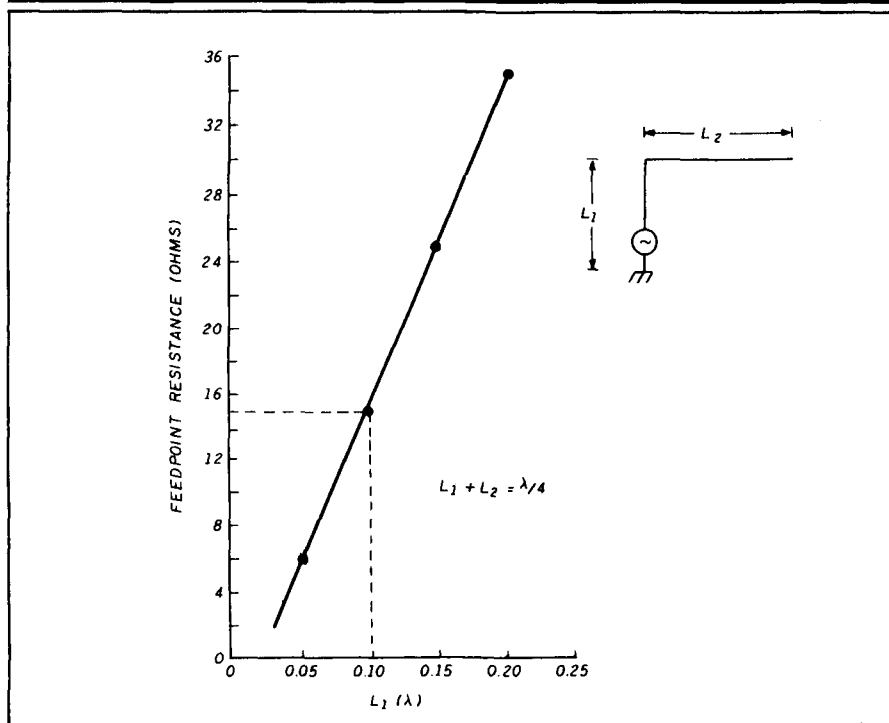
Last month I explained the technique of preparing antenna data for inclusion in K6STI's antenna analysis program.<sup>1</sup> The discussion covered program theory, the coordinate system used, and wire, segment pulses, and sources. All of this information is placed in a special format and input to the computer. The antenna in question may be modeled in free space or above ground. The program lets you specify ground conductivity in the area of the antenna. I model antennas in free space as the program runs more quickly. Elevation plots for antennas above ground are available in many handbooks. However, the books can't show the effect of lossy ground on the elevation patterns. This can be very pronounced, and isn't often something you can figure out intuitively. Thus, after the antenna is modeled in free space with satisfactory results, it's a good idea to run it again over simulated ground. Your local conductivity factor will give you an insight into the reflection gain.

### Modeling a sample antenna

As a working example, I'll discuss a popular 20-meter, three-element vertical beam. The design is shown in Figure 5. The antenna is built on a 22-foot boom. Elements are assumed to be 1 inch in diameter. (Element diameter and taper will be discussed in my next column.)

While linear element dimensions are

FIGURE 4



Bent-wire Marconi has low feedpoint resistance, depending on ratio of L<sub>1</sub> to L<sub>2</sub>. When L<sub>1</sub> is 0.1 wavelength, for example, feedpoint resistance is about 15 ohms.

shown, the MN program requires information in a different form. The tip position of all elements is expressed in X-Y-Z Cartesian coordinates. (Because the antenna is only two dimensional, the Z coordinates are zero.) The appropriate X-Y-Z data for this beam, plus other required information, are shown in Table 1.

To create an antenna file, you need a text editor or word processor. The MN package includes a text editor called TED. This is a short program and works much in the manner of WordStar™. You can use other programs, like EDLIN, if you wish. But TED does the job quickly and easily.

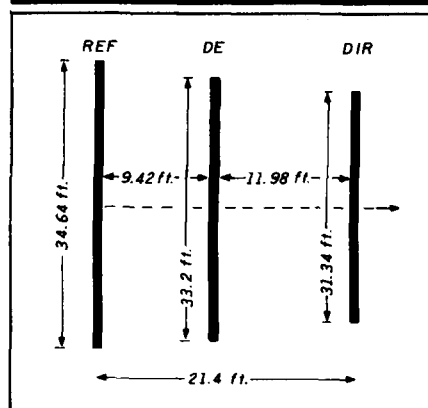
Once the information has been

placed in the word processor in the proper form, give the data a name and an extension (.ANT), and the file is entered into the antenna program. In this case, the name used is 3LYAGI.ANT.

After you view the antenna file for accuracy, start the computation to determine the gain, front-to-back ratio, and input resistance (impedance) by giving the command "G". In this example (using a math coprocessor) the matrix fill time is 21 seconds. The computed antenna information is shown in Table 2.

This particular antenna is designed for good gain with a high degree of front-to-back ratio. About 1 dB of the

FIGURE 5



Three-element 20-meter Yagi. Design frequency is 14.175 MHz.

maximum possible gain is sacrificed to achieve this favorable ratio. Input impedance is good, with the driven element being slightly short for the design frequency of 14.175 MHz.

Note that my printer used an italic "x" in place of the percentage sign in the beamwidth printout. IBM clones and printers occasionally have little idiosyncrasies like this and some diddling with the dip switches is required (sigh).

The last step in the program is to display the directive pattern. If you want to print it, you'll need a dot matrix printer (see Figure 6). And there you have it! All of this vital data is derived without cutting a single piece of aluminum or climbing even one foot up a tower!

### The antenna file

The MN program has a library of many different antenna files which you can examine before you input your own design. It's a good idea to examine these files to get the "feel" of how the program works and how the data is input to the program. Start with a simple antenna, like a dipole or two-element Yagi. Note how the X-Y-Z coordinates are derived and pay attention to the spaces between statements, letters, and numbers within the individual lines. If results seem odd, examine the RUN file to see if you have allocated pulses and the source properly. You'll find that reviewing the antennas in the file, before you run your own program, pays big dividends. MN has built-in prompts which lead you step by step to the conclusion. You may be dismayed at some of the ego-deflating gain figures for beam antennas

TABLE 1

Program for 20-meter beam. See Reference 1 for explanation of entries.			
Three-element 20-Meter Yagi			
14.175 MHz			
Free Space			
3 wires, feet			
10	-10.7,-17.32,0	-10.7,17.32,0	0.083
10	-1.28,-16.6,0	-1.28,16.6,0	0.083
10	10.7,-15.67,0	10.7,15.67,0	0.083
1 source			
14			
0			

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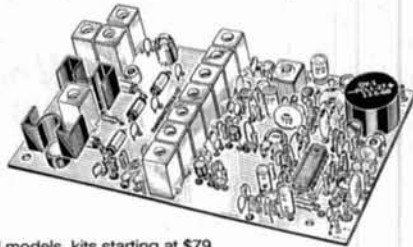
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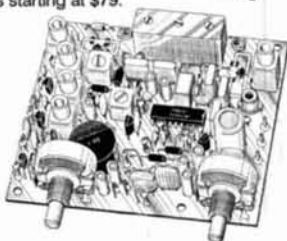
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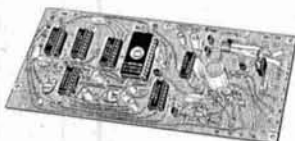


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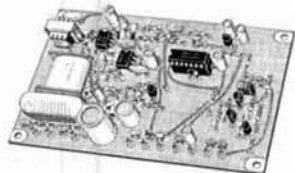


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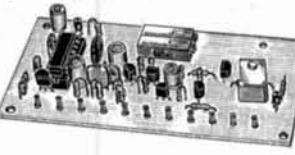
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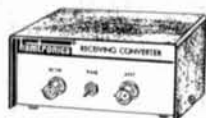
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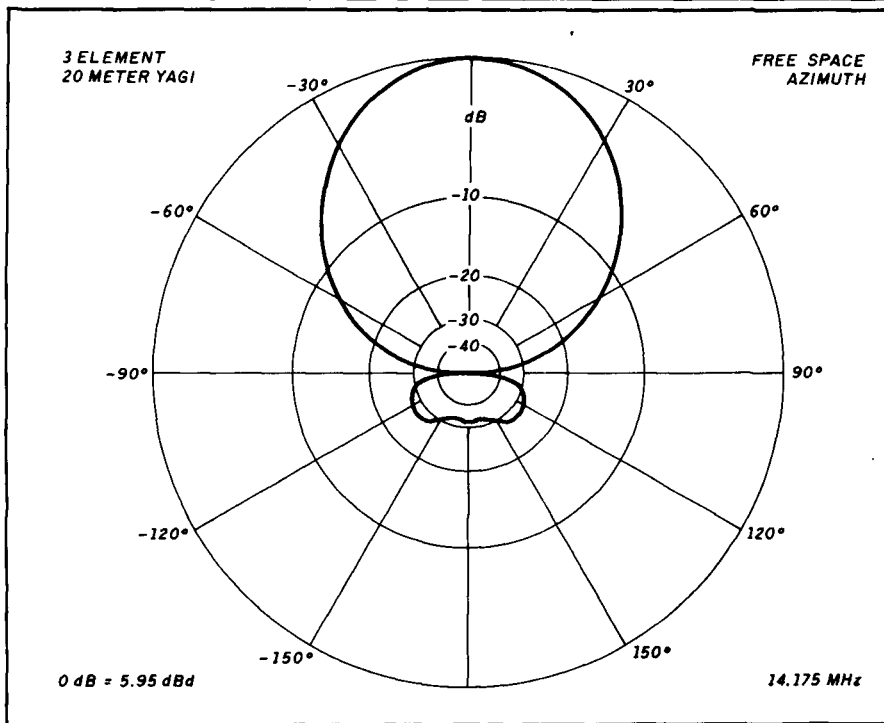
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FIGURE 6



Azimuth pattern of 20-meter Yagi combines good gain with excellent front-to-back ratio.

TABLE 2

Twenty-meter beam has 5.95 dBd gain, over 31 dB front-to-back ratio and feed-point impedance of about 22 ohms. (See text regarding beamwidth printout.)

Matrix Fill Time	0:21
Matrix Factor Time	0:02
Impedance	22.3 -j 3.9 ohms
SWR	2.26 for Z = 50 ohms
Forward Gain	5.95 dBd
F/B	31.83 dB
Maximum Sidelobe	26.98 dB down at 124x Azimuth
Azimuth Beamwidth	63x
Elevation Beamwidth	100x

provided by MN which contradict highly touted figures given by some beam antenna manufacturers, but that's the way it is.

Next month I'll review the Yagi optimizer program which lets you manipulate the dimensions of your antenna and see what happens when you change length, spacing, and taper of Yagi antennas. Stay tuned!

### The Dead Band Quiz

Thanks to the following additional readers who responded to my problem about the snowplow. (See last month's column for the solution.) They are: AC5P, KE2MO, N6SVI, NG5F, WY7U/4, James Conley (no call given), W6MUR, WA7HVT, and K4KQS.

Some readers have requested a "literary quiz" instead of a mathematical-type problem. So here are two little quizzes to whet your appetite:

"Remain on patrol in vicinity of Rockall."

This unusual signal was sent by whom to whom? What was the approximate date the signal was sent, and what was the significance? What, or who, is Rockall? What is the story and who is the author?

The second quiz concerns a popular TV show now in rerun. Who said the following and under what circumstances?

"Brain! Brain! What is brain?"

Good luck and see you down the log. Written replies to these little brain teasers will be acknowledged in this column. My QTH: Box 7805, Menlo Park, California 94025.

#### REFERENCES

1. Bill Orr, W6SAI. "Ham Radio Techniques: The MN Analysis Program (That was then; this is now)." *Ham Radio*, February 1990, page 34.

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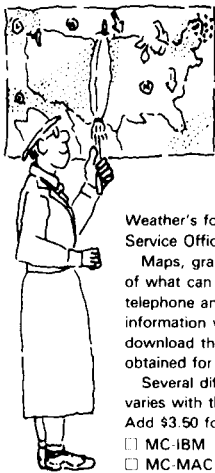
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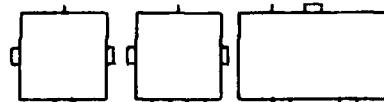
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### Digital voice storage on the IBM PC

By Carl Lyster, WA4ADG, 4412 Damas Road, Knoxville, Tennessee 37921

In my February 1989 *Ham Radio* article,<sup>1</sup> I described the basic principles of a digital voice storage playback only device suitable for use as a repeater IDer. This month I'll discuss the hardware and software required to add digital voice storage capability to any of the IBM series of PCs or clones. In addition to giving you the ability to store and play back audio in the range of 1 Hz to 5 kHz, this project lets you program audio passages in ROM for use with the voice IDer.

This device is the result of years of tinkering with A/D and D/A converters attached to microcomputers. My initial work was done with a South West Technical Products 6800 computer. I then progressed through PDP-11/34s to the IBM PC. I made each transition in search of more memory in an effort to lengthen the storage time. The IBM, with its 640K of memory and bussed card slots, is a natural choice for hardware experimentation.

In 1987 I packed an IBM PC along with a gas generator and an earlier version of this card to the Dayton Hamvention™ flea market. I was overwhelmed by the interest shown and suggestions of possible uses for this concept. It has taken a year of reworking the design to make it easily reproducible and I hope it may form a de facto standard for Amateur Radio digital voice on the IBM. The applications for this technology are limitless and can be put to immediate use by hams in such areas as aids to the blind, simplex repeaters, and voice mailboxes. I'm hoping this article will inspire professional programmers to create some sophisticated software packages.

#### Description

This card, when installed in an IBM or clone, allows the digitization of human speech, storage of the passage on hard or floppy disk, editing of the digitized voice, and

playback through a suitable audio amplifier or transmitter. A frequency response of 5 kHz gives a fidelity comparable to a narrowband FM 2-meter signal. The digitization rate is 10K samples per second set by software timing loops and therefore changeable by keyboard command. At this standard rate of 10K samples/second a 640K IBM CPU will store about 46 seconds of continuous voice. Some memory is used by DOS, the BASIC interpreter, and the digitizing program itself. I chose to use the BASIC language because it handles binary files easily and is almost universally popular.

#### Technical information

My hardware takes advantage of some clever design work by the people at IBM. They realized the need to dedicate a small portion of the I/O address space available in the PC to "hardware hacker" types like me. This I/O area lies in the range of 300 hex to 31F hex and is given to the whim of the computer user. Any user-supplied device operating in this I/O area should be free of interference to or from the computer. Naturally, several mail order electronics firms realized this potential and have developed easy-to-use prototyping cards which operate in this user I/O area. To date, my work has been done with a prototyping card called the PR2, sold by JDR Microdevices. I recommend their card for this project and any other which requires bus interfacing to the IBM.

#### Hardware description

Your project can take one of two forms. First, you may purchase a PR2 card and hand assemble the circuit (see Figure 1) on the card using its on-board logic. This reduces the complexity somewhat but results in greater expense. Second, you may follow the pc board artwork I have provided (see Figures 2 and 3). It contains all of the elec-

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tronics on a one-third length double-sided pc board. This is the simplest and most compact method and will provide better rejection of computer-generated noise. I've built many units using both types of construction and have been pleased with all of them.

The digitization and playback is performed by a pair of ICs produced by analog devices. I used the AD 7224 D/A converter for playback and the AD 7574 A/D converter for recording. These are eight-bit converters which fit the addressing scheme of the IBM nicely (one data point or sample equals eight bits or one byte). The dynamic range of the recording is approximately 48 dB with a frequency response of 1 Hz to 5 kHz.

Signal flow for the one-third length card is as follows. During recording, audio enters the card at a maximum level of 0.5 volts p-p and is amplified and level shifted by op amp IC1. The gain is set to 10 by R1 and R2, and the DC offset or "bias" of the amplified signal is adjusted by pot VR1 to 2.5 volts DC with no audio present. The resulting level-shifted audio will swing from 0 to 5 volts for an input of 0.5 volts p-p. Under software timing, a machine language write to I/O port 304 hex starts the A/D conversion sequence.

The A/D IC-11 converter responds by lowering its busy flag (pin 14), which causes IC2 (a sample and hold chip) to store temporarily the present amplitude of the audio signal. A sample and hold chip is analogous to a capacitor that can be turned on or off by a TTL level (the busy flag). The stored output of the sample and hold chip is then filtered by an eighth order equal component Sallen-Key low pass filter. I described the operation of this filter in my February 1989 article, so I won't go into detail here. After about 20  $\mu$ s the A/D converter finishes digitizing the sampled audio and clears its busy flag. The software timing loop then issues a read command to I/O port 304 hex. This retrieves the digitized data from the A/D converter and stores it in the CPU, which transfers the data byte to RAM memory. The timing loop restarts the entire process 1/10,000 of a second later for the next data point. When the desired RAM space has been filled, the software program halts the recording process.

The digitized passage is reproduced when the CPU retrieves a data byte from RAM and sends it via a machine language write to I/O port 308 hex, D/A converter IC10. The AD 7224 digital to analog converter produces an output voltage proportional to the magnitude of the binary number it is sent. Binary 00000000=0 volt DC, binary 10000000=2.5 volts DC, and binary 11111111=5 volts DC. The analog voltage output is then filtered by an eighth order Sallen-Key low pass filter, identical to the one in the recording unit, to remove any frequency components above 5 kHz that would cause aliasing. The reproduced audio is sent off the card to an external audio amplifier or transmitter. Software timing loops instruct the CPU to retrieve the next data point from RAM 1/10,000 of a second later and repeat the process until the desired time has elapsed.

IC 7, 8, and 9 form an I/O port decoder which operates in the user I/O area. Pin 14 of the decoder (IC9) goes low for address 304 hex to 307 hex to select the A/D converter; pin 13 goes low for address 308 hex to 30B hex to select the D/A converter. I didn't provide external bus buffering because both converters contain on-chip buffering, which has proven to be sufficient for the most heavily populated motherboards. You can obtain power for this card from the

computer's busses, but my experience has shown them to be too noisy for low level audio use. Because of this, I use two voltage regulators and two zener diodes to ensure ripple free power. Raw  $\pm$  12 volt supplies from the computer's card slot are first regulated down to  $\pm$  8 volts for the low pass filters and the sample and hold chip. The 8-volt supplies are then regulated down by zener diodes to  $\pm$  5 volt supplies that are used as references for the converter chips. The CPU's bulk 5-volt logic supply powers the Vcc requirements of the voice card's ICs directly.

Those who elect to build their project on a PR2 card won't need to assemble the I/O port decoder because the PR2 contains nearly identical electronics.

## Checkout and adjustment

After you've built the card and inserted it into the computer, you can run two short programs\* to verify proper operation and adjustment of pot VR1. Program ADTEST.BAS (Listing 1) is used to adjust VR1. This program is loaded under BASIC just like any other. It samples the voltage present at the audio input jack continuously and displays the magnitude, in decimal, of the converted data point. With no audio applied to the card, adjust pot VR1 to display a value of  $128 \pm 1$  on the screen. This corresponds to 2.5 volts DC. After you've adjusted VR1 correctly, connect an audio source of 0.5 volts p-p to the card and run ADTEST.BAS again. Data point values ranging between 0 and 255 should appear randomly on the screen. This program samples the A/D converter much too slowly to store audio; it is for test purposes only.

DATEST.BAS (Listing 2) checks the D/A converter for proper operation. This program generates a slow sawtoothed waveform that can be observed with a scope or meter movement type multimeter. A clean ramp from 0 to 5 volts DC on the scope or a smoothly moving needle on the multimeter indicates a functional D/A converter and low pass filter.

Please keep in mind that the audio output of this card is DC coupled and may need to be isolated from your external device by a blocking capacitor of about 5  $\mu$ F.

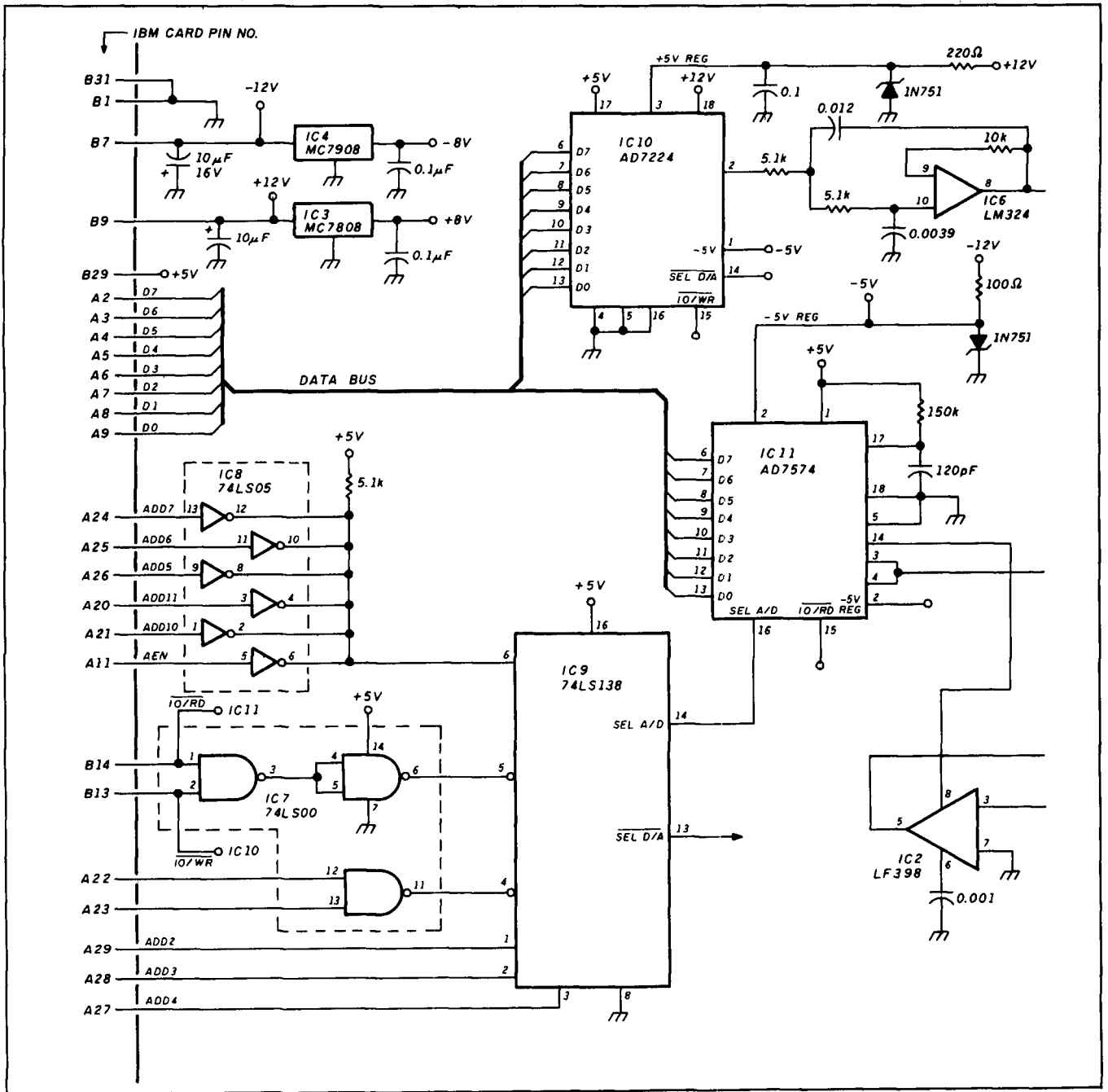
## Operating software

The software to perform the voice digitization and playback consists of two machine language subroutines (Listings 3 and 4) that are "poked" by BASIC into RAM memory. The bulk of the BASIC program, HAMTALK (Listing 5), is used to save and retrieve binary files containing the digitized audio. My program is limited due to the lack of space and a desire to spare you from having to enter several hundred lines of code. It does provide the ability to save and retrieve voice on disk, alter the sampling rate for experimentation purposes, and program ROM for the voice I/O. Because of the simplicity of this program, it will only store up to 25 seconds of voice. A more sophisticated program that makes use of the full memory capacity of the IBM and allows editing of the recording in memory is available from me on two 5.25-inch floppy disks.

The program HAMTALK.BAS will operate with GWBASIC or BASICA. When starting BASIC, you must use the /M switch to set aside RAM space for the machine language subroutines. Do so by typing BASICA /M:15000 and, after receiving the BASIC "OK" prompt, starting the program by

\* Listings 1-5 are available from Ham Radio for an SASE with \$25 postage.

FIGURE 1



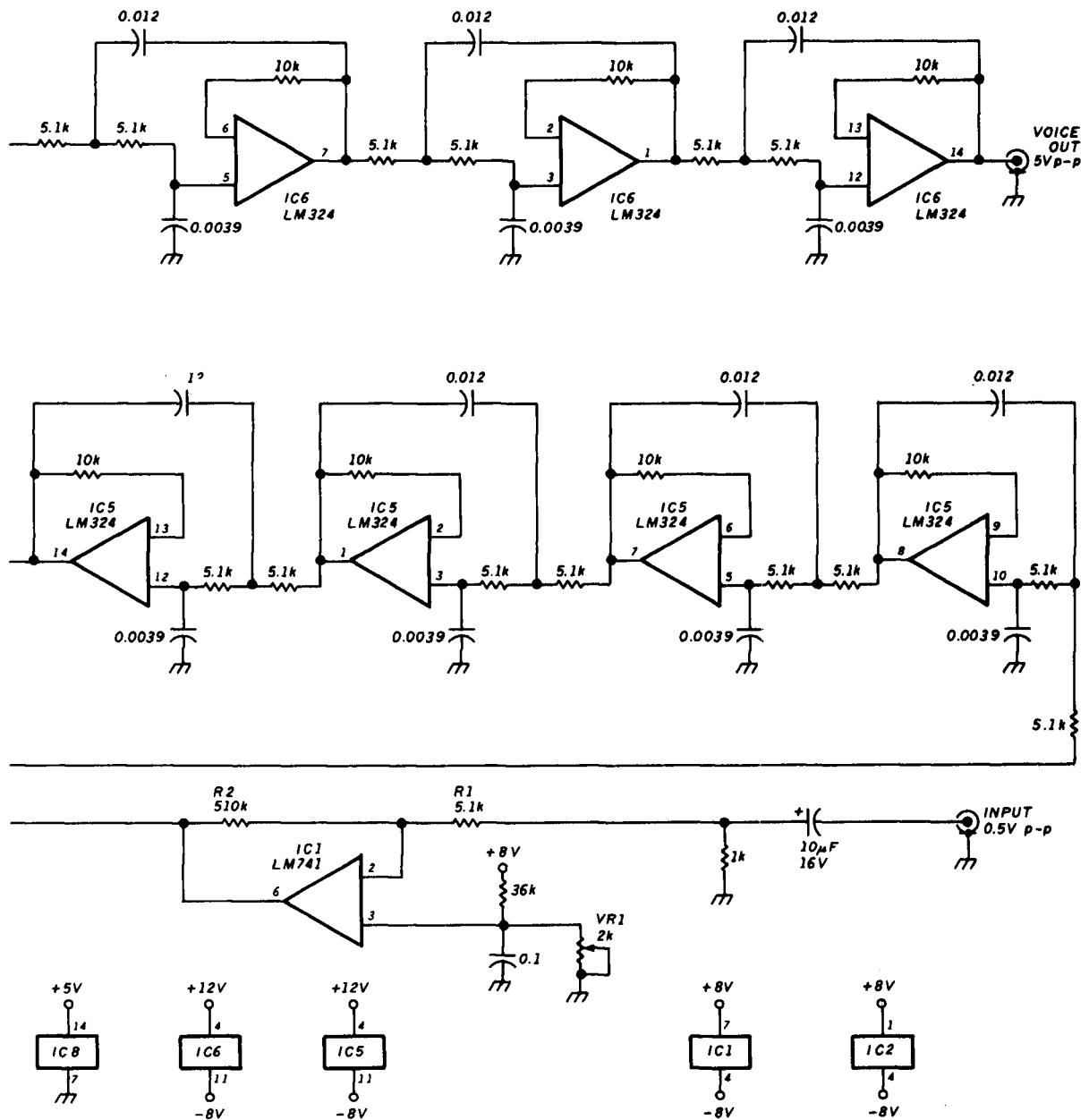
Circuit diagram.

typing RUN HAMTALK. The screen will clear and a menu will appear. I've set aside 256K of memory for the voice buffer. This corresponds to about 25 seconds of continuous voice. *Your machine must have at least 512K of RAM to operate. Any less will result in your voice buffer overwriting DOS, which will hopelessly lock up your computer.* A short summary of the menu choices follows.

- R The R command starts the recording of 256K worth of memory, normally about 25 seconds.
- P The P command starts the playback of the 256K voice buffer.

- D The D command allows keyboard selection of the digital sampling rate. The default value is 11, which corresponds to 10K samples per second on a 4.77-MHz machine. If your PC operates faster than 4.77 MHz, you'll have to increase D proportionately.
- Q The Q command returns you to DOS.
- DIR The DIR command displays a directory of the voice files contained on the default disk drive (the drive where BASICA resides).
- S The S command saves the voice buffer to disk. The buffer is composed of four files of 64K. Each file is 6.4 seconds long. If you wish to save the first 12

FIGURE 1



seconds of the buffer, you must save two files. Three files would save the first 19 seconds and four files would save the entire 25-second buffer. You'll be prompted to enter the number of files to save and then asked for a name to store the files under. For instance, if you enter four files with the name TEST, the program will save your buffer as four files with the names TEST1.BAS, TEST2.BAS, TEST3.BAS, and TEST4.BAS. Each file will represent one 64K segment of the voice buffer.

G The G command retrieves voice files from disk and stores them in the voice buffer. You are prompted for

the number of files you want to retrieve and the file names.

### Hard drive notes

I strongly recommend that you use a hard drive. There's a quantum leap in file access time between a floppy and a hard disk. If you place your software on a hard disk, *do not* store the voice program or voice files in a subdirectory; place them in the root directory. I have found that the use of subdirectories slows the access time of the hard disk by a factor of 4.

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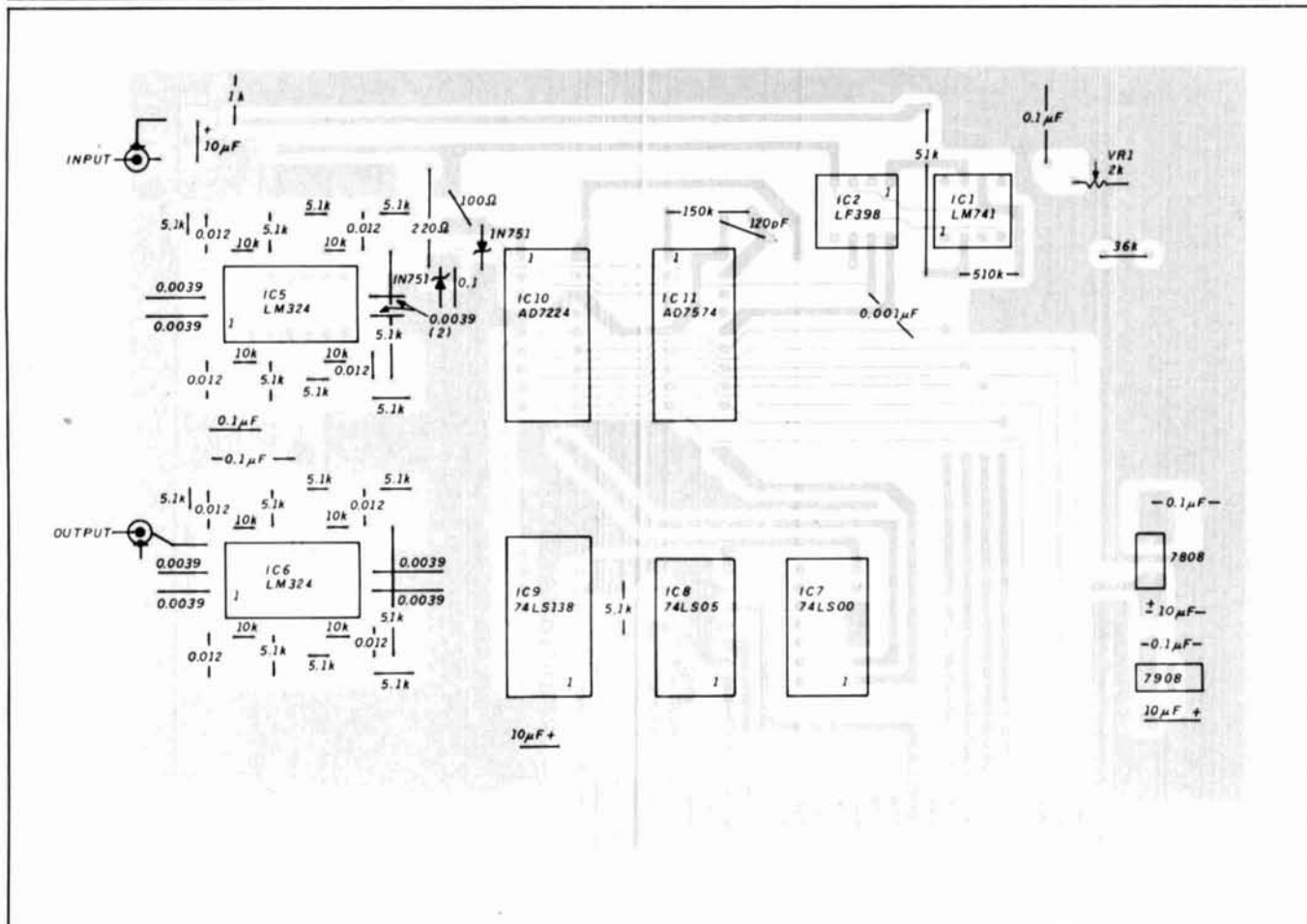
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FIGURE 2



PC board artwork, component side.

PARTS LIST

<b>Capacitors</b>	
1 120-pF	50-volts DC disc
8 0.0039- $\mu$ F	50-volts DC metallized film, Digi-Key P4558
1 0.001- $\mu$ F	50-volts DC disc
8 0.012- $\mu$ F	50-volts DC metallized film, Digi-Key P4514
4 0.1- $\mu$ F	50-volts DC disc
3 10- $\mu$ F	16-volt electrolytic (radial)
<b>Resistors</b>	
1 100 ohm, 1/4 watt	
1 220 ohm, 1/4 watt	
1 1 k, 1/4 watt	
17 5.1 k, 1/4 watt	
9 10 k, 1/4 watt	
1 36 k, 1/4 watt	
1 51 k, 1/4 watt	
1 150 k, 1/4 watt	
1 510 k, 1/4 watt	
<b>Potentiometer</b>	
1 2-k trimpot, Digi-Key D1AA23	

<b>Semiconductors</b>	
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2 LM324 quad op amp	
1 LF398 sample and hold amp	
1 LM741 high performance op amp	
1 MC7808 three term, +8 volt, 1-A regulator	
1 MC7908 three term, -8 volt, 1-A regulator	
1 74LS00 quad 2 input NAND gate	
1 74LS05 hex inverter	
1 74LS138 expandable 3/8 decoder	
1 AD7224* D/A converter	
1 AD7574* A/D converter	
1 printed circuit board**	

\* Available from Allied Electronics and Pioneer Standard Electronics outlets nationwide.

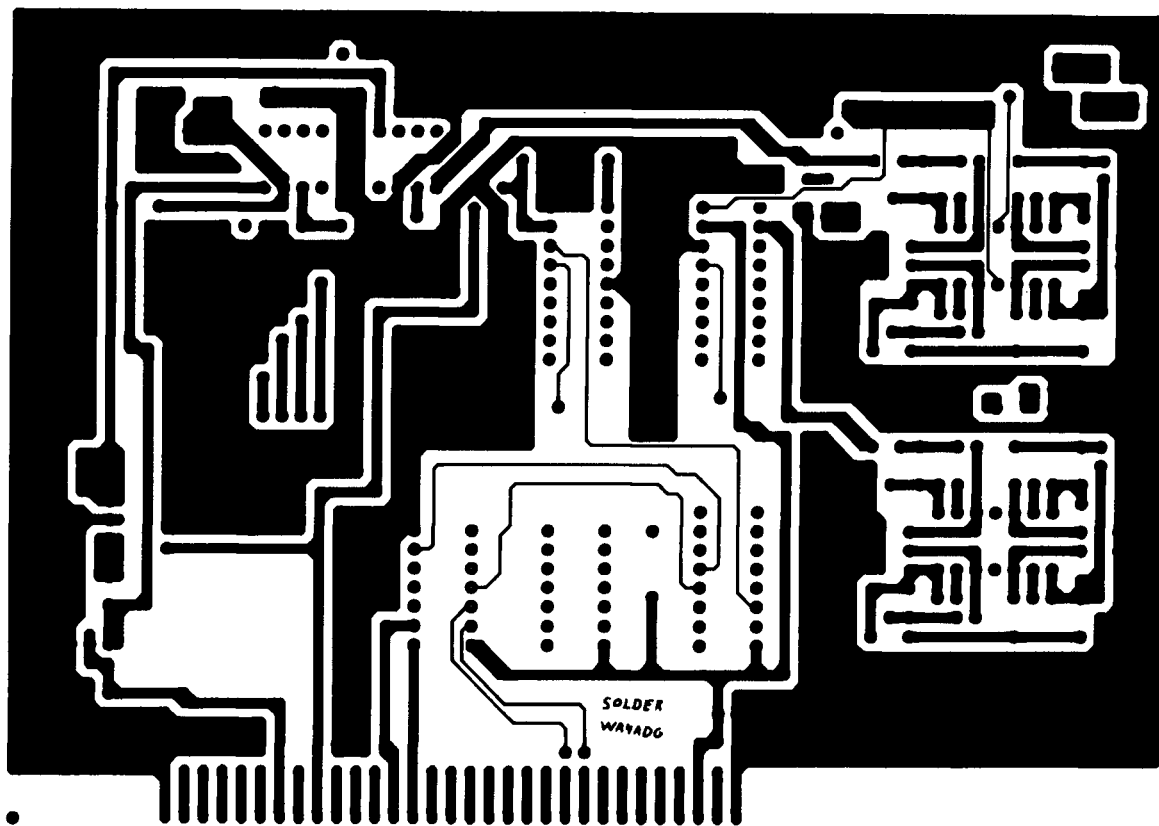
\*\* Available from FARCircuits, 18N640 Field Court, Dundee, Illinois 60118 for \$15 each. Boards do not have plated-through holes and component leads must be soldered on each side of the pc board.

Mathematical theorems — hearing is believing!

In my first article, I gave a brief description of voice storage and the theories of digital sampling. You may recall the Nyquist theorem stated that a sine wave must be sampled at least twice per cycle in order to be reproducible. This project can convey the reality of the Nyquist theorem far better than any text book. I stated earlier that the sampling rate will be 10 kHz with a 4.77-MHz CPU and a "D" of 11.

With a low pass filter response of 5 KHz, a D of 11 is absolutely the slowest sampling rate that falls within the rules of the Nyquist theorem. When the D value is changed to 12, which slows the sampling rate to about 9.5 kHz, you can literally hear the reproduced audio "falling apart." This is characterized by a ringing sensation that's the result of misreproduced frequencies. I have provided the ability to change the sampling rate just for this purpose, to illustrate graphically a rule which we are becoming more dependent upon each day.

FIGURE 3



PC board artwork, trace side.

## Programming EPROMS

HAMTALK.BAS stores voice files in binary format. These files can be read by an EPROM programmer, sold by JDR Microdevices. The programmer that I've been using was sold under the name "Sunshine Programmer." It has been replaced by a new version that costs about \$130. If you own a different EPROM burner, you may have to be creative in order to get the data from disk into your particular programmer. You might try moving memory blocks with machine language subroutines to an area of memory used by your programmer or dumping the disk file out of a serial port. In any case, once the data is in your programmer, simply program the appropriate chip (being careful to use the correct voltage), then place the EPROM in your voice storage unit.

If there's sufficient interest, I'll design a low cost programmer to fit the IBM bus and read the voice files and program 27256 or 27512 chips in BASIC. Please write and let me know if this is something that you're interested in.

### Program subroutines for voice digitization and playback

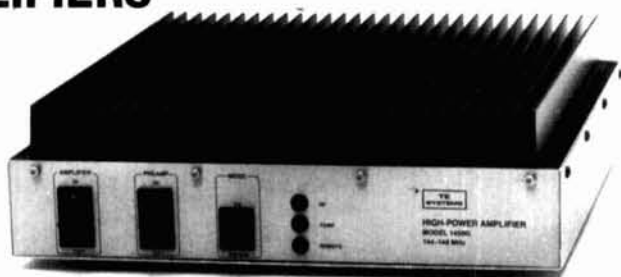
You can add voice capability to your favorite program

once you understand the working principles of the record and playback subroutines. Both routines are written in machine relocatable code. This means they can be placed anywhere in RAM memory. You must take care to ensure that the RAM where these routines are placed is truly free and won't be used by other programs. Both playback and record routines contain starting and stopping addresses for the voice buffer, as well as a delay number to control the sampling rate.

To use the record routine, first set the starting and stopping addresses in hex of the range of RAM you wish to fill. In BASIC language, you'd POKE these values into the subroutines. If you wish to change the sampling rate, you'll also have to POKE a new value for the delay factor. This wouldn't normally be necessary. Keep in mind that a designed sample rate of 10 kHz will fill FFFF hex locations in 6.4 seconds. After setting the address, simply use a call subroutine statement to start the digitization. When the subroutine finishes digitizing the desired amount of RAM, a "return far" (RETF) instruction returns control to your program. The voice buffer is now filled and can be saved to disk or reproduced by the playback routine. The playback subroutine is used in much the same way as the record routine. Set the starting and ending addresses of the voice buffer and then call the

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1452G	144-148	25	400	.6	15	13.6	50	UHF
2252G	220-225	25	250	.7	14	13.6	36	UHF
4450G	420-450	10	180	1.1	12	13.6	39	N
4452G	420-450	25	180	1.1	12	13.6	36	N

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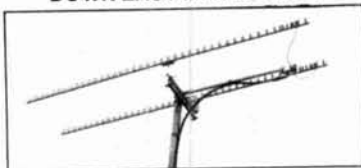
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subroutine. It is assumed that your program has either previously digitized a passage into the voice buffer or filled the buffer from disk. The RETF command returns control to your program after the voice passage has been reproduced.

Before I present a detailed operation of the subroutines, a short simplified description of how the IBM addresses its RAM will eliminate a great deal of confusion. A common CPU, like the old 8080, addresses memory with 16 binary address lines A0 to A15. This gives 65,536 separate addressable bytes, 0 to FFFF hex. The 8088 can address 1,048,576 bytes directly using address lines A0 to A19, corresponding to 0 to FFFFF hex. The addressing confusion arises when you try to store a 20-bit wide address in a 16-bit wide register! Intel has solved the problem using a segment register and an offset register combined to produce a 20-bit wide address. For the purposes of this software and to keep life simple, consider the segment register to be nothing more than a bank select register which allows you to choose one of 16 64K byte banks. The offset register contains the address location in the currently selected 64K bank. The correct method of describing a memory address using this scheme would look like this: segment address to the left of the colon, offset address to the right of the colon. One example might be 1000:3FFF, which corresponds to bank 1 offset 3FFF. For your purposes, the segment register or "bank select" register will only contain one of 16 values. These are in hex and range from 0000 to F000. The first digit is the "bank number" and the 000 portion is necessary filler. The banks are tabulated below.

0000:= 1st 64K bank	8000:= 9th 64K bank
1000:= 2nd 64K bank	9000:= 10th 64K bank
2000:= 3rd 64K bank	A000:= 11th 64K bank
3000:= 4th 64K bank	B000:= 12th 64K bank
4000:= 5th 64K bank	C000:= 13th 64K bank
5000:= 6th 64K bank	D000:= 14th 64K bank
6000:= 7th 64K bank	E000:= 15th 64K bank
7000:= 8th 64K bank	F000:= 16th 64K bank

This scheme forms a simple method for the voice routines to access the entire RAM space of the CPU. When one 64K byte bank is full, simply increment the segment register by 1000 hex to select the next 64K byte bank. In reality, the segment:offset operation of the CPU is much more complicated than this brief description.

One last important point. Because the timing loops for the digitization are software generated, all processing by the CPU must be halted during the voice routine operation; this includes the keyboard input! To accomplish this, each voice routine turns off all possible interrupts while running and then enables interrupts at completion of the routine. Both routines load the voice buffer starting address with an MOV BX,0000 for the offset address and an MOV DI,2000 for the bank address. This equates to byte zero of the third bank — just above and out of the way of BASIC. The ending addresses are loaded as part of compare instructions like CMP BX,0000 for the offset register and CMP DI,6000 for the segment register. You may change these starting and stopping points to any location in RAM as long as you don't overwrite a resident program, like DOS!

Next time I'll discuss combining a clone motherboard with this month's project, along with ROM or RAM based software, into a digital voice storage simplex repeater suitable for whatever RF frequency you choose. 

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# Practically Speaking

Joseph J. Carr, K4IPV

## ANALOG METER MOVEMENTS: HOW TO USE THEM

Although the digital meter has popped up all over the electronics industry, it's noteworthy that a lot of Amateur Radio equipment, both factory made and homebrew, still uses the analog meter movement. At the last large hamfest I attended, I saw that analog meters were popular among those who pored over the tailgaters' offerings.

Why, in an age of digital everything, is the analog meter still popular? I think there are two basic reasons. First, the analog meter isn't terribly sensitive to RF fields that surround Amateur Radio gear. Second, this meter is most often used in Amateur Radio to find peaks and dips rather than an actual value. While the digital meter has a certain edge over analog types when it comes to reading values with ease, its very nature makes looking for peaks and dips annoying — especially if the integration of the digital meter is long!

In this month's column I'll look at analog meters and their applications. While I don't expect to exhaust the field, this information should be useful for a wide variety of Amateur Radio metering applications. I'll examine the basic DC meter movements and a method or two for making them read AC values.

### DC instruments

The two most common forms of DC meter movement are the *D'Arsonval* and *taut band* designs. Both movements are examples of a general class called *permanent magnet moving coil (PMMC) galvanometers*. These devices work on the same basic principle as the DC motor. A simplified view of the PMMC movement is shown in **Figures 1A** and **1B**. A movable coil is mounted in the magnetic field between

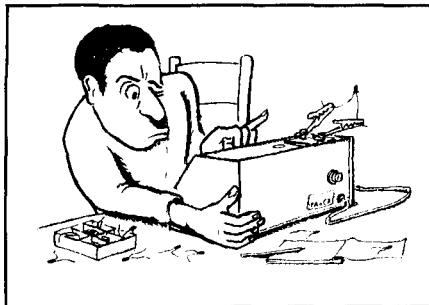
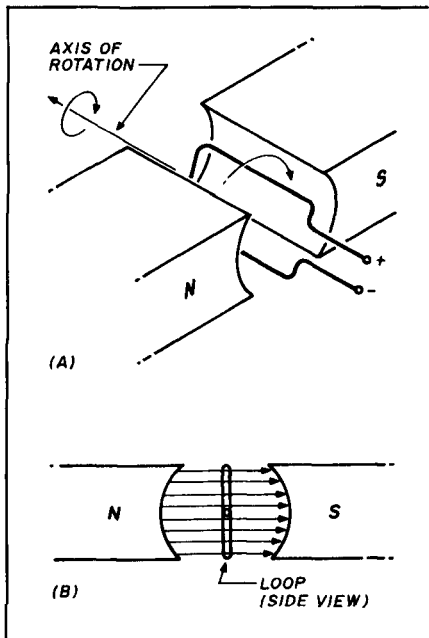
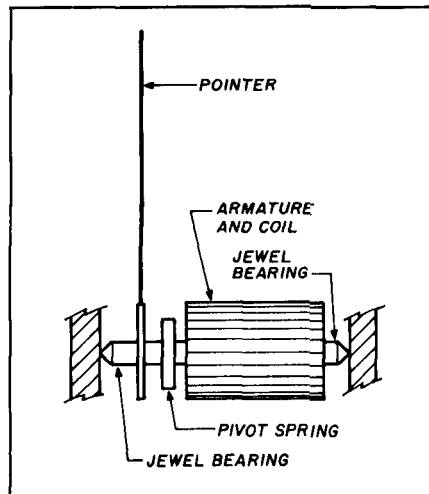


FIGURE 1



(A) Permanent magnet moving coil (PMMC) galvanometer. (B) Side view.

FIGURE 2A



Side view of the D'Arsonval meter movement.

the two poles of a permanent magnet. A current flowing in the wire generates a magnetic field. The polarity of the magnetic field is determined by the direction of the current flow, while the strength of the field is determined by the current magnitude.

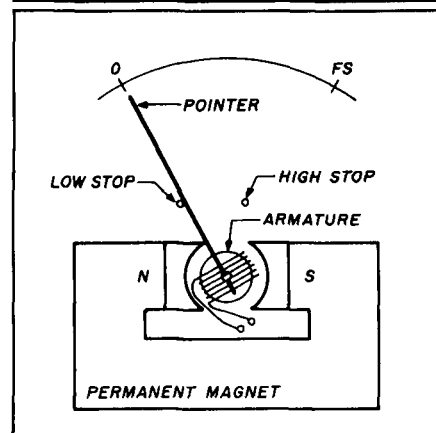
The coil of a PMMC movement is mounted so it can rotate in the space between the magnet poles. A current in the coil creates a magnetic field that either aids or opposes the field of the nearby magnet poles. Current flow in one direction causes a clockwise rotation; current flow in the opposite direction causes a counterclockwise rotation. The amount of rotational position change is proportional to the current magnitude.

### The D'Arsonval meter movement

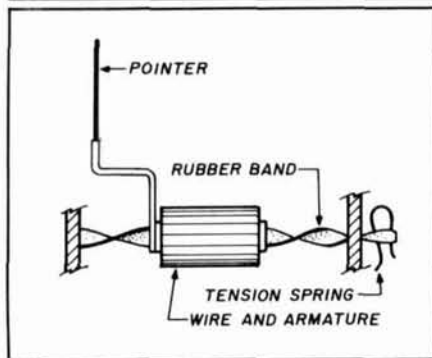
Figure 2 shows the D'Arsonval meter movement. A side view of the meter movement, without the permanent magnet, appears in **Figure 2A**; a front view of the magnet is shown in **Figure 2B**. The coil in **Figure 2A** is wound on an armature (or bobbin) which is mounted on a pair of jeweled bearings to reduce friction (see **Figure 2B**).

When a current flows in the coil, the armature assembly deflects clockwise (as illustrated in **Figure 2B**) by an amount proportional to the current strength. The amount of deflection can be marked in units of current on the

FIGURE 2B



End view of the movement.

**FIGURE 3****Side view of the taut band meter movement.**

dial scale. The coiled pivot spring dampens the pointer movement and returns the pointer to the zero position when the current flow in the coil ceases.

The travel of the pointer is limited by high and low end mechanical stops just beyond the zero and full scale limits printed on the dial scale. The wires to the coil are given just enough slack so that they won't be stretched anywhere in the pointer's normal range of travel. Overranging, however, can cause damage to both the pointer and the spring.

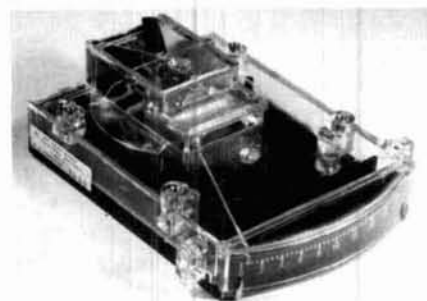
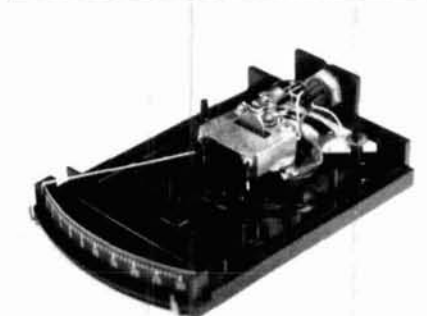
### The taut band meter movement

The taut band meter movement is essentially the same as the D'Arsonval movement, except for the manner in which the armature is mounted (see Figure 3). In the taut band meter movement, the armature is suspended from fixed supports on a stretched (taut) rubber band. The band is twisted as the armature rotates, so no restoring force from a pivot spring is needed.

There are two principal advantages of the taut band meter movement over the older D'Arsonval meter movement — greater sensitivity and durability.

Older D'Arsonval meter movements are rarely found with full scale deflection sensitivities less than  $50 \mu\text{A}$ , but there are taut band models available that boast a full scale value of only  $2 \mu\text{A}$ .

D'Arsonval meter movements are more easily damaged than taut band types because their jeweled bearings are more fragile. Even a short fall to the floor or bench top is sufficient in many cases to destroy the D'Arsonval meter movement (although some are notably more robust). The rubber band can snap in a taut band meter, but this occurs less frequently than does bearing damage.

**PHOTO A****Zero center meter movement.****PHOTO B****Edge mounted meter.****PHOTO C****Internal view of edge mounted meter.****PHOTO D****Expanded scale meter.**

## Types of analog meter movement

The two basic PMMC meter movements are available in a large array of sizes and types, but only a few can represent a wide spectrum of models. Meters can be classified according to the type of scale. The standard form shows zero on the left and full scale (FS) on the far right.

The terminals on the back of the meter indicate which terminal is positive. When the meter is connected to a circuit with the positive terminal to the positive side of the circuit, the deflection will be upscale when current flows. Reversing the connections forces the meter pointer backwards, and this may damage the meter.

Photo A shows the zero center PMMC galvanometer movement. This scale has the zero point in the center. Positive values are to the right and negative values are to the left.

Photo B shows an edgewise meter movement. This design lets you conserve valuable panel space at the expense of increased depth. An interior view of this meter is shown in Photo C. Edgewise meters are available in both left and center zero models. The movement shown in Photos B and C has a pair of front panel tabs that can be used to set high and low limits for an alarm circuit. A pair of internal photocells and lamps are blinded when the meter pointer exceeds the set point. External circuitry can then detect the alarm condition.

Photo D shows an example of an expanded scale meter movement. The left-hand scale isn't zero, but has a voltage applied that's a little less than 100 volts AC. The expanded scale meter improves the meter's resolution in a range of interest. In Photo D the meter is used to monitor the AC power line voltage, which is normally constrained from 95 to 125 volts AC.

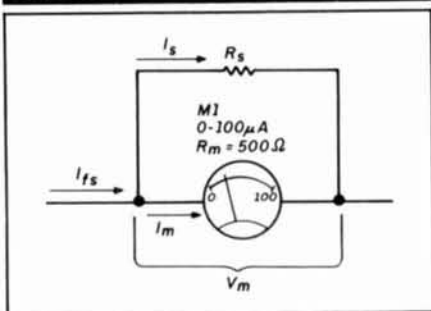
Photo E shows a meter that was once quite popular with Amateurs — the RF ammeter. This instrument has a left zero scale, but works differently from the normal PMMC instruments. Although a PMMC movement might be at the heart of this instrument, a thermocouple embedded in a resistive element inside the meter makes it work. Heat is generated when RF current flows in the resistive element. This heat causes a voltage to appear across the ends of the thermocouple. The voltage is proportional to the RF

**PHOTO E**



**Thermocouple RF ammeter.**

**FIGURE 4**



**Increasing current scale with a shunt resistor.**

current, although you should be able to tell from the scale that it's a nonlinear function of RF current.

**Using DC meters**

There are three basic rules to remember when using DC current meters:

- Connect the meter in series with the load or circuit in which it is used.
- Use a meter that has a full scale current reading greater than the expected current flow.
- Use a meter that has a low internal resistance compared with the circuit in which it is being used.

A current meter is *always* connected in series with the load. Failure to observe this simple precaution can, and most likely will, result in total loss of the meter. In most cases, the series requirement means that the circuit will have to be interrupted physically for the meter to be installed.

**Apparent "errors" in meter readings**

Assuming that your meter is in good shape, there's a possibility of an error in your readings if the meter resistance, relative to the circuit resistances, is so

high that it interferes with proper circuit operation. The current in a circuit is normally  $V/(R_s + R_L + R_m)$ , where  $R_s$  is the internal resistance of the power supply and  $R_L$  is the load resistance. If the meter resistance ( $R_m$ ) is a significant fraction of the other two resistances, then the meter will read less current than actually flowed in the circuit before the meter was installed.

**Obtaining high DC current scales**

The basic DC meter movement has a single current scale like 0 to 1 mA, 0 to 100  $\mu$ A, and so forth. You can measure larger currents if you connect a shunt resistor in parallel with the basic meter movement (see Figure 4). In some cases the meter shunt is internal to the meter movement (Figure 5A); in other cases it's external (Figure 5B). An external shunt is usually bolted to the meter terminals (Figure 5C).

For shunted meters, the actual meter movement full scale rating is often printed in small letters on the lower right or left side of the scale. By the way, it's common for a meter that normally takes an external shunt to show up at a hamfest *sans shunt*. You might think that the meter is rated for 0 to 1000 mA, only to find out that it is a 0 to 1-mA movement and requires a shunt to make it read the higher scale! Watch out; this can destroy the instrument.

The full scale current ( $I_{fs}$ ) flowing in the circuit of Figure 4 is given by Kirchoff's current law:

$$I_{fs} = I_m + I_s \tag{1}$$

where

$I_{fs}$  is the full scale current.

$I_m$  is the current flowing in the meter coil.

$I_s$  is the current flowing in the meter shunt resistor.

There are two basic methods for calculating the value of the shunt resistor — Ohm's law and the current divider equation.

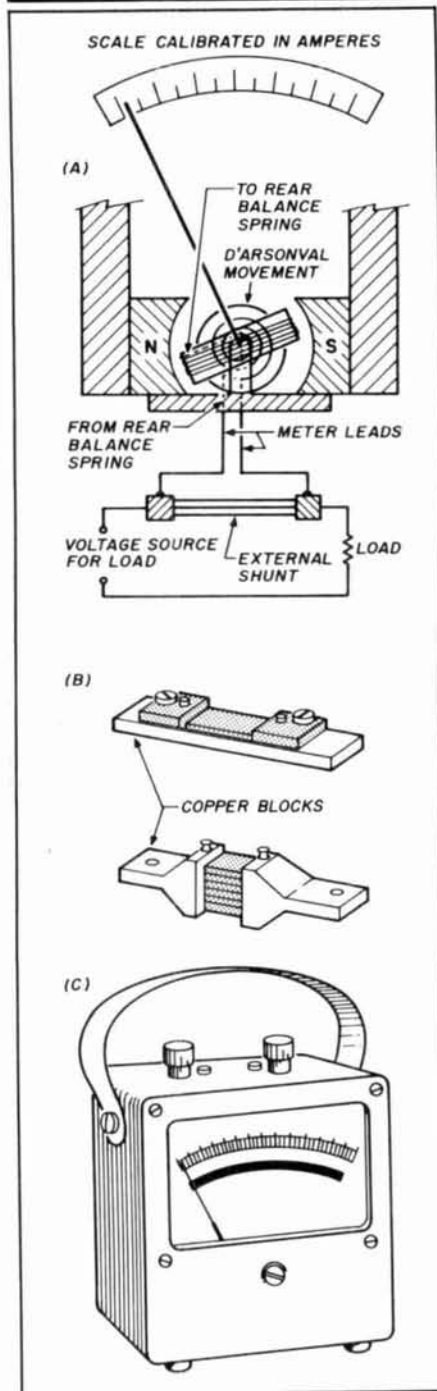
**Ohm's law method**

If you know the full scale current rating of the meter movement (M1) and the coil resistance ( $R_m$ ), you know by Ohm's law that the voltage drop across the meter at full scale is  $V_m = I_{fs}R_m$ , or in the case shown in Figure 4:

$$\begin{aligned} V_m &= I_{fs}R_m & (2) \\ &= 10_{-4} A (500 \text{ ohms}) \\ &= 0.05 \text{ volt} \end{aligned}$$

Because  $R_s$  is in parallel with M1, the same voltage is also present across  $R_s$ . Consider the case where you want the meter to indicate 1 mA (1000  $\mu$ A) at full scale. Because 100  $\mu$ A flows in the meter, you'd expect to find a current of  $I_s = 1000 \mu A - I_{fs} = 900 \mu A$  in the shunt resistor when using Equation 1. You can therefore calculate the resistance needed to make a new full scale

**FIGURE 5**



(A) Internal shunt. (B) External shunts. (C) External view of meter.



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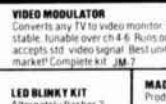
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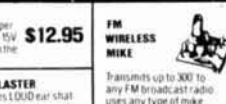
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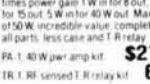
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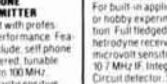
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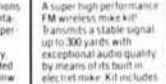
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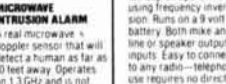
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### FM MINI MIKE

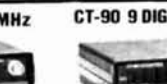
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CT-50	5 Hz-600 MHz	< 25mv @ 50 MHz < 15mv @ 500 MHz < 100mv @ 800 MHz	1 PPM	8	1 Hz, 10 Hz	189.95
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current  $I_{fs}'$  by:

$$R_s = \frac{V_m}{I_s} \quad (3)$$

$$= (0.05 \text{ volts DC}) / (9 \times 10^{-4} \text{ A})$$

$$= 55.556 \text{ ohms}$$

Put in another form, this procedure reduces to:

$$R_s = \frac{I_m R_m}{I_{fs}' - I_{fs}} \quad (4)$$

### Current divider method

The alternative method takes advantage of the current divider equation:

$$I_s = \frac{I_{fs}' R_m}{R_m + R_s} \quad (5)$$

If you solve this equation for  $R_s$ , you find the resistance of the shunt:

$$R_s = \frac{R_m (I_{fs}' - I_s)}{I_s} \quad (6)$$

### Voltage measurement from the DC current meter

You can measure voltage on a DC current meter if you connect a multiplier resistor ( $R_{mx}$ ) in series with the meter movement, as in Figure 6A. The circuit is redrawn in Figure 6B to make it easier to understand. The current in the circuit is:

$$I = \frac{V}{R_{mx} + R_m} \quad (7)$$

By solving Equation 7 for  $R_{mx}$ , you can calculate the required value of multiplier resistor:

$$R_{mx} = \frac{V_{fs} - I_m R_m}{I_m} \quad (8)$$

where

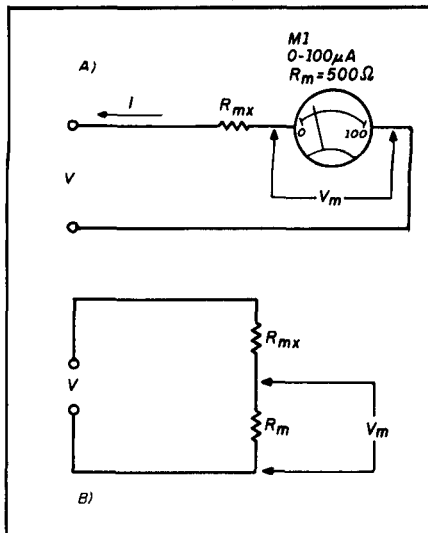
$R_{mx}$  is the multiplier resistance.

$V_{fs}$  is the desired full scale voltage.

$I_m$  is the meter current at full scale.

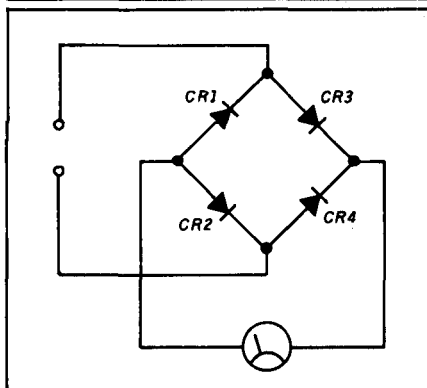
$R_m$  is the meter resistance.

FIGURE 6



(A) Multiplier resistor makes current meter into a voltmeter. (B) Circuit redrawn.

FIGURE 7



Bridge rectifier makes DC meter into an AC meter.

### Voltmeter sensitivity

The sensitivity of the DC voltmeter is measured in terms of ohms per volt. It depends on the full scale current of the basic DC meter movement used in the circuit. You can find the sensitivity quickly by taking the reciprocal of the full scale current rating:

$$S = 1/I_f \quad (9)$$

Table 1 gives the sensitivities of

popular meter movements. The impedance of the DC voltmeter is found from its sensitivity:

$$Z = V_{fs} \times S \quad (10)$$

You need to know the impedance when determining whether or not a particular meter will load the circuit.

### Reading AC on DC meters

Although there are several different forms of AC meters, it's common practice to use a DC meter movement for measuring AC values in multimeters and other applications. The simplest method is to use a bridge instrumentation rectifier (see Figure 7). This rectifier circuit will produce a reading that's approximately 0.9 times the peak voltage, but you can calibrate the scale in terms of rms voltage. However, that calibration is based on the premise that the AC remains a sine wave. If the sine wave is distorted, or if a non-sinusoidal wave is being measured, then the calibration is shot.

The rectifiers used in Figure 7 (CR1 to CR4) are, ideally, copper oxide instrumentation rectifiers for 60-Hz work. You can use silicon (1N4148) or germanium (1N60) rectifiers as well — especially if you're making RF measurements.

A more complex form of rectifier is based on the fact that op amp circuitry can be used to calculate the true rms value of the waveform. Several IC manufacturers offer devices that are listed as rms-to-DC converters.

### Next month

This month I've examined the meter movement itself and some applications, like voltmeter and AC meter. In the next (and final) installment of this series I'll take a look at some meter applications circuits. **hr**

TABLE 1

Full Scale Meter Current, $\mu\text{A}$	Sensitivity, ohms/volt
1000	1,000
100	10,000
50	20,000
20	50,000
10	100 k



# NEW PRODUCTS

## Commander HF-2500 Linear Amplifier

Command Technologies introduces the Commander HF-2500 linear amplifier. The HF-2500 operates on 160, 80, 40, 20, and 15 meters. It also performs on the WARC bands, and can operate on 12 and 10 meters with user modification.

This amplifier delivers 1,500 watts of continuous carrier output using a pair of Eimac 3CX800A7 triodes requiring only 50 to 80 watts of drive. High duty cycle emissions like RTTY, SSTV, FM, and AM present no problems. Tuned input and ALC adjustments can be made from the rear panel. The interior chassis layout provides full cabinet pressurized forced air cooling. Parts and labor are covered by a three-year limited warranty. With sales and service factory direct, the Commander HF-2500 sells for \$2,188.

Write to Command Technologies, Inc., PO Box 939, Bryan, Ohio 43506 for further information or call toll free (800)736-0443.

Circle #303 on Reader Service Card.

## CM-1200 SWR/Power Meter

NCG has announced the new CM-1200 Ultra-compact SWR/Power Meter for 1200 MHz. It's rated at maximum power 60 watts for power ranges of 10 to 60 watts. Insertion loss is 0.25 dB and normal impedance is 50 ohms. The connectors are N type; dimensions are 2.25" width x 2.55" height x 1.1" diameter.

For more information contact NCG Company, 1275 N. Grove Street, Anaheim, California 92806.

Circle #304 on Reader Service Card.

## Morse Code Terminal Kit and New Repeater Log

Dynamic Electronics Inc. announces a Morse Code Terminal Kit that converts a Radio Shack color computer into a Morse terminal. The conversion kit lets you send Morse code by pressing a key on the keyboard — decoding and printing the characters on the television screen or monitor. Interface cables (included) connect from the receiver's audio to the right joystick port and from the key jack to the printer or RS-232 port. The key cable is wired for a three conductor 1/4-inch plug and can be adapted to a two conductor 1/8-inch plug with an adapter (not included).

Features include automatic speed tracking on receive, preprogrammed message transmission with a single keystroke, and message transmission from a file on a tape or disk.

The program works on all 32K and larger

Radio Shack color computers with extended BASIC using either tape or disk drives. The keyer will key a solid-state transceiver with a maximum keyup voltage of 15 volts. The cost of the kit is only \$39.95 plus \$3 shipping. Specify tape or disk software.

Dynamic Electronics Inc. also has a new Repeater Log Program for Tandy color disk and IBM compatible computers. The log lets you enter up to 200 repeaters in a file and list them by frequency, city, or callsign. Each file has spaces for city, repeater callsign, offset used, and comments. Additional files can be loaded for different beam headings or states. The cost is \$14.95 plus \$2 shipping. Please state IBM or Tandy color computer.

More information about the Morse Terminal Kit and Repeater Log Program can be obtained by contacting Dynamic Electronics Inc., PO Box 896, Hartselle, Alabama 35640. Phone: (205)773-2758.

Circle #305 on Reader Service Card.

## Communicator Enhancer

Electronic Specialists improved modular connector communication enhancers now include Common Mode RFI and low frequency interference filtering. Available as integral parts of Spike/Surge Suppressors, the improved models provide modem and FAX transmissions with greatly reduced errors.



Dubbed the TURBO, improved communication enhancers are available for the standard single line modular plug (RJ-11) systems and commercial multi-line connector systems such as RJ-13, -14 and -45. Multiple connector systems can also be custom engineered. Models incorporating AC power line conditioners, filters or filter/suppressors are available.

TURBO models are available from stock, starting at \$49. For more details contact Electronic Specialists, Inc., 171 So. Main Street, Natick, Massachusetts 01760. Call toll free: (800) 225-4876.

Circle #306 on Reader Service Card.

## Two New Rotatable Dipoles

SV Products has two new rotatable dipoles. The model 1824D (25-foot elements) covers the two new WARC bands, 12 and 17 meters. The 2128D (22.4-foot elements) is for the DXer's bands, 10 and 15 meters. KD9SV uses a new trap design for high strength and power handling capability. The trap has been tested to 25 kV and will easily handle full legal power. Antenna elements are made from high strength T-60612 aluminum alloy. Windloading is less than 1 square foot and the antenna will rotate with a standard TV rotator. Introductory price for both antennas is \$89.95 plus \$5 shipping and handling.

For more information contact Gary Nichols, KD9SV, 4100 Fahlsing Road, Woodburn, Illinois 46797.

Circle #307 on Reader Service Card.

## Transistor Radio Kit and Training Course

The AM-FM-108 Transistor Radio Kit is designed to expand your understanding of basic radio theory. Circuits are laid out in systematic order on an oversized pc board so you can easily understand the flow of the radio signals from antenna to speaker.

Construction begins with the building of the AM Radio, static testing of each circuit, and then dynamic testing with voltage and signals. After completing the AM Radio section, you construct and test the FM Radio circuit. Alignment procedures complete the projects. The radio kit pc board needs no cabinet. A special bracket provides support to use or display the radio in any location.

A complete manual is included along with a magic wand that assists in the alignment of RF circuits. Earphone, battery, and magic wand are included. The list price of the kit is \$29.95.

For further information contact Elenco Electronics, Inc., 150 W. Carpenter Avenue, Wheeling, Illinois 60090. Telephone: (312)541-3800. FAX: (312)520-0085.

Circle #308 on Reader Service Card.

# New Products

## Scanner and Shortwave Answer Book

Bob Grove's *Scanner and Shortwave Answer Book* answers hundreds of questions asked by shortwave listeners. This 160-page reference was compiled from eight years of questions submitted to *Monitoring Times* by its readers.

Grove's book is \$12.95 (plus \$2 shipping in the U.S.) and is available from Grove Enterprises, PO Box 98, Brasstown, North Carolina 28902. Telephone (704)837-9200.

Circle #309 on Reader Service Card.

## ICOM Options for the IC-901 Fiber Optic Multi-band Transceiver

The IC-901 fiber optic remote mount multi-band transceiver offers a variety of options to meet your mobile needs. New options available to complete your IC-901 multiband package include:

Unit	Description	Suggested Retail Price
UX-S92A	2-meter SSB band unit complete with USB, LSB and CW modes	\$599.00
SP-12	Slim Line External Speaker with Visor Clip for mobiles	\$ 25.99
OPC-23	DC cable	\$ 33.49
EX-766	Interface-A Connector	\$ 47.99
EX-767	Interface-B Connector	\$ 42.99

For details contact ICOM America Inc., 2380 116th Avenue NE, PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #310 on Reader Service Card.

## Kantronics Data/Voice Radio

Kantronics has introduced the first radio specifically designed for the packet enthusiast. The new Kantronics dvr 2-2 provides high speed T/R switching for today's digital world.

The dvr 2-2 reaches full power output (rated at 2 watts) within 5 ms after push-to-talk is activated. In addition, the dvr 2-2 has a fast carrier detect output that reacts within 10 ms after a signal is received. This lets you set your TXDELAY to 2 (20 ms) when talking to another dvr 2-2 user. This carrier detect helps reduce collisions, as the radio senses activity faster and signals the TNC that the channel is in use.

The dvr 2-2 also has discriminator output available on the rear panel connector, which means you don't have to modify the radio for high speed packet. The unit was designed with the ability to operate at up to 9600 baud without modifi-

cation. The connections to your packet modem are all provided on a single DB-9 data port on the rear panel.

The dvr 2-2 data port is designed to be pin-for-pin compatible with Kantronics TNCs, but the dvr 2-2 will operate with other manufacturers' units also. The increase in speed realized by our pin diode T/R switching can result in a reduction of your TXDELAY setting by as much as 90 percent or more.

The dvr 2-2 has a microphone jack on the rear panel, allowing you to connect the optional Kantronics mic and an external speaker for voice operation. You don't have to disconnect your packet unit to talk.

The suggested retail price for the dvr 2-2 is \$199. For details contact Kantronics, 1202 E. 23rd Street, Lawrence, Kansas 66046. Telephone: (913)842-7745.

Circle #311 on Reader Service Card.

## Heil Sound's Concept 2000

Heil Sound has introduced the Concept 2000 product line. Included in the lineup are: the HM-10 microphone, AB-1 adjustable microphone mount, FS-1 foot switch, and FL-1 private lighting system.

The Heil HM-10 uses the Heil "Key Element" microphone cartridge for maximum articulation of SSB transmissions. The HM-10 is available with either the HC-5 or the HC-4 Key Element. The HC-5 is a full range element rolling off below 300 Hz and has a 6-dB peak at 2100 Hz. The HC-4 "DX Dream Machine" was designed by Heil for breaking the DX pileups. It has the last octave rolled off at 600 Hz and has a 10-dB peak at 2100 Hz.

A special model of the HM-10 is available with both the HC-4 and the HC-5 installed. A professional four-pin Cannon connector in the base of the HM-10 is used to connect the microphone to your transceiver. A second micro-switch selects either the HC-4 or the HC-5.

The HM-10, shipped with mating cable assemblies, will match the HM-10 with your type of transceiver. The red cable is wired for Kenwood, Blue mates the ICOM, yellow matches up the YAESU, and a white cable is used for other transceivers and labeled as such. The slide switch on the HM-10 case is wired for standard push-to-talk while the Key Element is wired straight through for VOX operation all the time without special switching or cabling.

The AB-1 is an adjustable mount to support the HM-10 or similar professional microphones. Its adjustable boom and mounting assembly can be used in a variety of ways.

The FS-1 has been designed to control the push-to-talk lines of a radio transmitter, allowing hands-free operation. This device has a 2-A momentary switch connected to a 4-foot shielded cable and is designed to switch low voltage circuitry. Switching 110-volt AC circuits with the FS-1 is not recommended.

The cable is terminated with a 1/4-inch phone plug. Should your equipment require a different interface, it is not recommended that you use any type of adapter but rather replace the existing connector with the correct matching plug.

The FL-1 is a private lighting system to illuminate radio panels, log sheets, or operating positions. The FL-1 is shipped with a conventional 12-volt incandescent lamp that can be powered with any 12 to 14-volt 100-mA power supplies. A halogen bulb is available to fit inside the FL-1 should you want more candlepower.

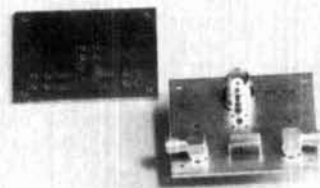
Additional information on Concept 2000 products is available from Heil Sound, Ltd., 2 Heil Drive, Marissa, Illinois 62257. Telephone: (618)295-3000.

Circle #312 on Reader Service Card.

## Evaluation/Prototyping Board with Sockets: TFM Series Mixers

RF Prototype Systems introduces the TFM1 Quick Board. The TFM is for evaluation or breadboarding using the following Mini-Circuits devices, and equivalent devices manufactured by Pulsar Microwave, Tele-Tech, Engelmann Microwave, Synergy Microwave and Olektron: TFM mixers, TSC splitters and TDC couplers. Connections to BNC, SMA, or SMB connectors are via 50-ohm microstrip lines.

Mounting holes for three bulkhead BNC, PCB, SMA or SMB connectors are provided.



A socketed version, TFM1S, allows the devices and TFM1S to be reused easily without soldering for frequencies up to 2 GHz.

This board is double-sided FR-4 (high temperature G-10) with plated-through holes.

For more information, contact RF Prototype Systems, 12730 Kestrel Street, San Diego, California 92129. Phone: (619)538-6771.

Circle #313 on Reader Service Card.

# UNDERSTANDING COMPUTER-GENERATED RFI

## Some remedies for this malady

By Bryan P. Bergeron, NU1N, 30 Gardner Road,  
Apt. 1G, Brookline, Massachusetts 02146

**R**adio Frequency Interference (RFI) has always been a source of concern for the Radio Amateur. Until the recent introduction of complex circuitry in the home (like microcomputer systems, VCRs, and microwave ovens), our communications gear has been the main source of potential RFI. In this computerized age of ours, increasingly complex and sensitive receivers are being barraged by these and other sources of RFI.

Microcomputers have become an integral part of the contemporary Amateur Radio station. Virtually all modern receivers and transceivers rely on microcomputer-controlled circuitry for their internal operation. But more important, from the perspective of RFI generation, is the external stand-alone microcomputer system. This system can be found in an ever-increasing number of Amateur Radio stations running programs for predicting HF propagation, logging and checking QSOs, printing QSL cards, and even controlling transceivers. Unfortunately, many computer systems radiate a significant amount of RF into the shack. This is especially true on the HF bands, where even a small amount of RFI can mask an otherwise readable signal. This article examines the microcomputer as a source of RFI, and suggests some steps you can take to contain it.

To understand how the microcomputer can be a source of RF interference, you must have some knowledge of how microcomputers are constructed, how they operate, and how they are normally connected to other devices.

### Physical Construction

On the most basic or physical level, most microcomputers are composed of a system unit, power supply, keyboard, and display screen. Depending on the make and model of the microcomputer, these components may be physically separate, as in the IBM PC, or found in a single package, as in many portable computers. Many microcomputers include the power supply and at least one floppy disk drive in the same physical enclosure as the system unit. Other models have the power supply and disk drives packaged separately. Many of the popular microcomputers have slots

for extending the basic system with plug-in modems, memory cards, and video cards for a variety of screens.

Few of us make do with the minimal system configuration. The most common additions are printers, extra disk drives, and modems. Adventuresome hams have packet controllers and interfaces to their microcomputer-based transceivers. All of these additional devices, and the cables that connect them to the system unit, are potential sources of RFI.

### Logical operation

For the purposes of this discussion, consider the microcomputer to be composed of a Central Processing Unit (CPU), memory, and a system clock. The CPU is the heart of the microcomputer. It not only performs operations on data that resides in memory, but also keeps track of the current status of the executing program and handles communications with memory and input/output devices like printers and modems. All of this activity must be carefully orchestrated for the microcomputer to function properly. The metronome for this activity, and a potential source of RFI, is the all-important *system clock*.

The system clock creates the timing signals used to synchronize all activities within the computer. And as in our modern transceivers, a quartz crystal normally serves as the basis for this timing. In some microcomputer systems the CPU contains the oscillator circuitry, so an external crystal is simply connected between two pins of the CPU chip. In other systems, separate dedicated chips are used to generate the timing signals. In the IBM PC/AT, for example, there's a clock generator chip and a programmable timer chip. The clock generator chip, which uses a quartz crystal, creates the basic timing signals used by the computer.

The programmable timer chip is related to the clock generator chip. Think of it as a programmable array of flip-flops that produces an output signal every so many clock cycles. For instance, if the basic clock cycle is 6 MHz (as in the original IBM-AT), and you want to perform some event every 1/60,000 second, the programmable timer chip can

TABLE 1

Clock frequencies for common microcomputer systems. Various speed-up methods and accelerator cards are used to speed up many of these machines (particularly older models).

Apple IIe/C	1 or 4 MHz
Apple IIgs	1 or 6 MHz
Commodore 64	1 MHz
Compaq Deskpro-286	8 MHz
IBM AT	6 (original) and 8 MHz (later)
IBM PC	4.77 MHz
IBM PS/2 Model 30	8 MHz
IBM PS/2 Model 50	10 MHz
Macintosh 512/Plus/SE	7.8 MHz
Macintosh SE-30	16 MHz
Macintosh II, IIx, IIcx	16 MHz

be programmed with a count of 100. At every 100th clock cycle, the programmable timer chip will produce a signal that can be used by the computer circuitry.

Obviously, RF energy at both the clock frequency and the variable programmable frequency (6 MHz and 60 kHz in the example above) are of concern to the Amateur. See **Table 1** for a listing of clock times used in the popular microcomputer systems. In some cases, the basic crystal oscillator circuitry operates at the same frequency as the system clock. For example, the 10-MHz IBM PS/2 Model 50 uses a 10-MHz crystal. In other instances, a crystal oscillator with a frequency higher than the clock frequency is used in conjunction with frequency divider circuitry. For example, the IBM PC uses a 14.32-MHz crystal with a clock frequency of 4.77 MHz (14.32 divided by 3).

## Power

Most microcomputers with built-in power supplies, like the Apple Macintosh and IBM PC/AT and PS/2 series, make use of internal lightweight switching power supplies. Switching supplies, unlike conventional linear supplies, do not make use of large iron core power transformers. Instead, the AC from the 110-volt power line is directed to a bridge rectifier, and the resulting ripple DC is pulsed at between 20 and 100 kHz. This pulsed, high frequency DC allows for the use of small, lightweight high frequency transformers. The pulsed DC and its harmonics are potential sources of RFI, through the power lines and cables to computer accessories. Also, whereas the relatively massive, high inductance power transformers effectively block RF radiation into the power lines, the high frequency transformers used in switching supplies can potentially couple RF more easily into the AC power line.

## Peripherals

Sooner or later most of us will add an electronic keyer, power amplifier, or beam antenna to our bare-bones rig. Similarly, those of us bitten by the computer bug are seldom satisfied with a minimally configured microcomputer. The most common additions include floppy and hard disk drives, various types of printers, modems, and alternative input devices. Depending on your computer's design, many of these additions may take the form of cards that plug into

the system, or external peripherals that must be connected by cables to the system unit. In order to understand how these devices can cause RFI, you must have a basic grasp of their operation.

## Alternative input devices

Although the keyboard is by far the most common method of interacting with the computer, there are various alternative input devices. What follows is a short description of the most common ones.

**The Mouse:** Some micros, like the Apple Macintosh, come factory equipped with this cursor control device. Other systems, like the IBM PS/2 series, have a mouse interface which lets you select a mouse of your choice. From an RFI perspective, the mouse, which is the most popular alternative or supplement to keyboard entry,<sup>1</sup> can be classified as mechanical or optical. The mechanical mouse uses a roller ball that moves as you control the mouse. Two perpendicular rollers (one for the x-axis and one for the y-axis) attached to contact pins are coupled to the roller ball. These contact pins make and break connections with a contact bar as the mouse moves, much like a distributor in an automobile engine. Optical mice are similar to mechanical mice in many respects; however, there are no physical make-and-break connections. They use LEDs and phototransistors to detect motion. As you might expect, the rapid make-and-break connections associated with mechanical mice can result in RFI. In comparison, optical mice are more electronically "clean." But, like any peripheral attached to the system via a cable, the mouse cord can act like a broadcast antenna for signals inside the system unit.

**Trackballs:** Trackballs are best thought of as inverted mechanical or optical mice. They offer the same benefits and limitations as the other mice in terms of their potential for RFI.

**Light Pens:** Light pens work by sensing the exact time that the electron beam in the monitor excites a phosphor at a particular point on the screen. The associated circuitry of the light pen determines the x-y coordinates of the point on the screen by measuring the time it takes for the electron beam to reach the pen. Light pens pass this information back to the computer through a cable, or in some cases, by sending an RF signal to a receiver mounted on the top of your monitor.<sup>2</sup> In directly wired systems, light pens generate low intensity signals only every 1/60 of a second. Assuming that the cable is adequately shielded, the potential for RFI is relatively low. RF light pens, in comparison, have a high RFI potential.

**Tablets:** Graphic tablets, useful for drawing and tracing, come in three basic types: electromagnetic, resistive, and acoustic.<sup>3</sup> The most RFI-prone type, the electromagnetic version, has a handheld pen that transmits an RF signal to a receiving grid located under the tablet surface. Tablet circuitry converts the signals into x-y coordinates to determine the pen's exact location.

Resistive tablets, sometimes called touch pad tablets, are made of two conductive surfaces separated by a small air gap. When a pen touches the tablet, bringing the two surfaces together, current flows between the two surfaces. The strength of the current is used to determine the x-y coordinates of the pen.

Acoustic tablets use a pen transmitting ultrasonic waves (65 to 75 kHz) that are received by microphones near the



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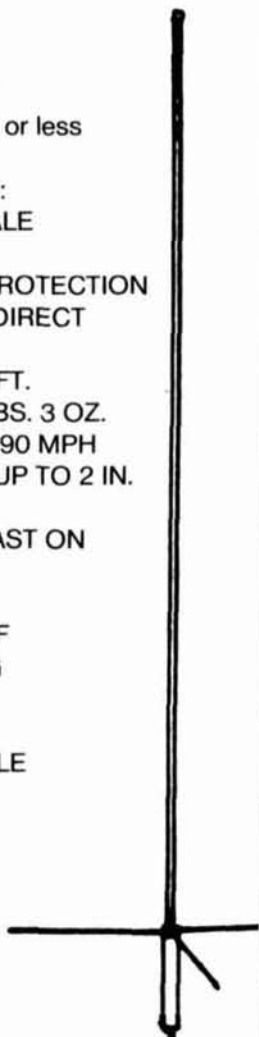
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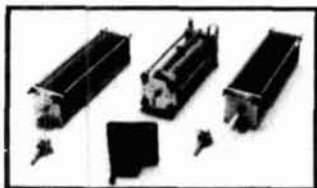
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W1FB 160/80 Pre Amp (QST 8/88).....\$22.95  
K9CW Memory Contest Keyer.....\$109.00  
Yaesu FRG-9600, .1 to 60 MHz Converter....\$84.95  
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✓ 166



work area. Through triangulation, the relative strength of the received signal at each microphone is used to calculate the relative x-y coordinates of the pen.

**Touch screens:** Touch screens, like light pens, are useful for selecting objects on the screen. The most common varieties are mechanical, optical, and capacitive. Optical screens use rows and columns of infrared LEDs — photo-transistor pairs mounted opposite each other along the edges of the screen. Touching a particular point on the screen with your finger blocks one or more x-y beams of light. The touch screen sends the coordinates of the broken beams to the computer, which calculates the corresponding x-y location on the screen.

Mechanical switching panels are composed of transparent, conductive membrane switches mounted over the display screen. Pressing your finger on the panel brings the two conductive surfaces together and completes the circuit. One sheet determines the x-axis and the other the y-axis location of the contact.

Capacitive touch screens have a capacitive coating on the CRT screen that acts as one plate of a capacitor. When you make contact with the screen, current flows into your body from the contact point. Sensors on the screen detect the location of the current drain and calculate the corresponding x-y location. In my experience, capacitive systems are more prone to RFI than either the mechanical or optical versions.

**Joysticks:** Although they are more popular as a game interface than a way of manipulating Amateur software programs, joysticks should not be overlooked as a source of RFI. The vast majority of joysticks are mechanical, composed of switches and/or potentiometers. The largest RFI threat from these simple devices occurs when the connecting cable acts as a radiator for system unit signals.

## Modems

Modems (named for **MOD**ulator-**DEM**odulator) let digital computers communicate over analog phone lines. In some microcomputer systems, like the Apple II series and the IBM PC/XT/AT, modem cards can be inserted easily into slots in the system unit. Along with minimizing the potential for RFI, these internal modems have the added benefit of providing a less cluttered ham shack. The more RFI-prone external modems, also popular on the IBM PC and other microcomputers, must be connected by a cable to the system unit. Purchasing an internal modem doesn't guarantee freedom from RFI, however, because the telephone cable represents a potential RF antenna.

## Printers

Printers range from simple dot-matrix units to complex laser printers that contain their own RF-producing microcomputer systems. Although a few printers attach directly to the system unit (primarily on portable models), the vast majority are connected to the system via cables. In my experience, the mechanical printers are less likely to cause RFI, but the acoustic noise they produce is hardly bearable during a QSO. The relatively silent laser printers, by comparison, emit considerable RF energy.

## RF modulators

Many of the lower priced microcomputers are designed to work with TV receivers as monitors. RF modulators con-

vert the video signal into a VHF signal that can be handled by a TV receiver (commonly on channel 3 or 4). These so-called "RF bricks" are potential sources of RFI — especially when the output is unshielded 300-ohm flat line.

## Local area networks

A local area network lets microcomputers communicate with other devices connected to the network, including modems, printers, computerized communications gear, and other microcomputers. ICOM's system allows multiple ICOM receivers and transceivers to communicate with each other and with microcomputers. Because this system directly connects your computer system to your communications gear, there's ample opportunity for RFI. In my experience with the ICOM system, there's no detectable RFI as long as the integrity of the cable and associated connectors are maintained. Other networks, like Apple's AppleTalk, can cause considerable RFI. AppleTalk is a low speed network often run over standard (unshielded) telephone cable. Receive on my ICOM 751A is rendered practically useless when AppleTalk is in operation.

## Minimizing computer-generated RFI

There are a number of steps you can take to minimize computer-generated RFI in your shack. In some cases, your problem may be cleared up by following only one or two of these measures. In more difficult situations, you may have to try all of these suggestions for acceptable results.

**Check the FCC rating before you buy:** Microcomputers are rated by the FCC as either Class A or Class B devices, depending on the amount of RFI produced by the equipment (see **Table 2**). Paradoxically, the often cheaper Class B machines, intended for home use, are less prone to RFI than the Class A machines. The more expensive Class A micros, including many micros based on the Intel 80386 chip and several of the large monitors, have less stringent RFI ratings. Unfortunately, many hams use the more powerful and more RFI-prone "business class" machines at home.

Think twice about a micro with a Class A FCC rating. Taming a machine with a Class B rating is difficult enough! Check the Model/Serial number tag on all computer equipment, including modems, printers, scanners, and mice before you buy. You should see an FCC ID number, together with a statement like "Certified to comply with the limits for Class B computing device pursuant to Subpart J of Part 15

TABLE 2

Radiation limits applied to microcomputers manufactured after January 1, 1981, based on data from subpart J of Part 15 of FCC rules.

Maximum radiation measured at 3 meters

	Class A	Class B
30-88 MHz	3,000 $\mu\text{V}/\text{m}$	100 $\mu\text{V}/\text{m}$
88-216 MHz	5,000 $\mu\text{V}/\text{m}$	150 $\mu\text{V}/\text{m}$
216-1000 MHz	7,000 $\mu\text{V}/\text{m}$	200 $\mu\text{V}/\text{m}$

Maximum conduction into the AC power line

0.45-1.6 MHz	1000 $\mu\text{V}$	250 $\mu\text{V}$
1.6-30 MHz	3000 $\mu\text{V}$	250 $\mu\text{V}$



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FCC rules." These rules are designed to provide "reasonable" protection against RFI in a residential installation.

**Shielding:** Don't defeat the shielding in your computer or peripherals. You may be tempted to remove the aluminized plastic backing from the Macintosh SE or Commodore 64 motherboard to prevent heat buildup. Don't! You will have a very cool-running RFI machine. Also, keep the rear metal card covers on your system unit intact. If you remove an internal card, make certain that you replace the original slot cover.

The new IBM PS/2 machines, like the original Macintosh series of computers, make heavy use of metalized plastic for shielding. Unlike the original PC and many of the PC clones these new lightweight machines limit metal shielding mainly to the power supply. If you aren't careful when opening these plastic cases, you might chip or wear away the conductive paint, and have a less than perfect RFI shield.

**Cables:** Use shielded cables whenever possible, and add snap-on ferrite inductors to peripheral cables — especially if they aren't shielded. You can use ferrite snap-on toroids to increase the series inductance of cables, raising their impedance to HF signals. Although adding significant inductance may have the effect of reducing the computer signals, the high frequency RF components will be attenuated to a greater degree. Peripherals (like external disk drives) that can create their own RF signals should have ferrite snap-on inductors attached to both ends of the cable. The inductor near the peripheral attenuates signals generated from within the peripheral, while the inductor near the computer system attenuates signals generated by the system clock that may be inadvertently coupled to the peripheral "antenna." Don't forget to add an inductor to the telephone cable where it exits your modem.

**Bypassing:** Judicious use of RF bypass capacitors with resistive touch pads, mechanical mice, and joysticks often pays off.

**Power Conditioning:** The simplest way to provide a good degree of isolation between your computer equipment and your receiver is to make certain that each system is controlled by different circuit breakers. Plug your computer and peripherals into a wall socket that is not connected to the socket used for your communications gear.

If using separate power circuits fails to remedy your RFI problem, or if all of the sockets in your shack are controlled by a single circuit breaker, try adding two good surge protectors to your shack — one for your communications gear and one for the computer equipment. A simple protector with MOVs won't do. The best method of isolating signals coupled through the power line uses a combination of RF line filters and transient suppressors. You can realize a 60-dB attenuation of interference above a few hundred kHz with RF line filters.<sup>4</sup>

**Ground:** Although you have no doubt heard it before, a good ground is essential for minimizing RFI. It's surprising how many hams who have 6-foot ground rods connected by heavy coaxial braid to their gear fail to ground their computer equipment. Treat your computer system, including all peripherals, like your communications gear where ground is concerned, and you should be well on your way to minimizing potential RFI.


**Layout:** Minimize cable lengths. When possible, use an internal modem instead of an external one with its associated cables. If RFI persists, try rearranging your equipment. Move your micro and peripherals as far from

your receiver as possible. In some cases, interference can be minimized to acceptable levels through proper layout of equipment and judicious cable runs. Obviously, running your external disk drive cable parallel and adjacent to the antenna feedline is asking for trouble.

**Communications Gear Modifications:** Try to minimize the number of possible entry points for computer-generated RFI into your system. If you have an external speaker with more than a few inches of cable, use a low pass filter and shielding to prevent the speaker wire from acting as an antenna.

**Software Design:** If you develop your own software, try to minimize the reading and writing of data to disk. Similarly, when you purchase software developed by others, run the program and make note of how often the disk drive whirs. The stepper motors and associated drive circuitry are extremely noisy in the RF spectrum.

## Summary

The best way to handle computer-generated RFI is to think of your computer system as you would any other piece of RF communications gear, with peripheral cables, phone connections, and power cords acting as the antenna system. Use low pass filters on all antennas (snap-on toroids on all cables and power cords), make certain that you provide a good system ground, use shielded cables of minimum length, and start with "RF-clean" gear. Use bypass capacitors whenever possible, and keep the computer "antenna system" away from your communications gear. 

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# AN LED MILLIVOLTMETER

By Yardley Beers, WØJF, 740 Willowbrook Road, Boulder, Colorado 80302

I've found a way to use light-emitting diodes (LEDs) to display rapid changes in voltage. Here are the construction details for a device with four LEDs where the number illuminated depends upon the input voltage. Without amplification, the voltages which turn on the lights are about 100, 200, 300, and 400 mV, respectively. A built-in DC amplifier can be switched in to increase the voltage sensitivity by a factor of 100.

## Some uses

A gadget of this type can serve as an inexpensive and compact substitute for a cathode-ray oscilloscope. You can display changes in voltage and see them from a considerable distance. It's especially useful when the voltages are changing very rapidly. You can also use it to display the output of a signal strength meter which is remotely located from a circuit being adjusted for maximum signal strength. The device is useful for demonstrating the generation of induced emfs to a class of beginners. Just connect a 1-1/2 inch coil with 25 turns to the input. Using a string, pull a small bar magnet through the coil. All four LEDs will light briefly.

I've included information for designing your own instrument using different numbers of LEDs to improve the resolution. You can also make the response logarithmic instead of linear.

A recent *Ham Radio* article discussed many of the fundamental properties of LEDs, but didn't mention their fast response times.<sup>1</sup> In fact, it's possible to build an inexpensive but low resolution oscilloscope using a square array of LEDs.<sup>2</sup>

## How it works

The principle of operation is illustrated by the circuit in **Figure 1**. Its principal components are an LED and an integrated circuit, U1 — a comparator. This IC, like an op amp, has two inputs and an output. However, there's no internal feedback which tends to make the voltages at the input terminals equal. The LED and a current-limiting resistor,  $R_L$ , are connected in series between the output terminal and the positive terminal of the battery, which powers the instrument. The signal voltage is applied to the negative input terminal, while the positive input terminal is connected to a voltage determined by resistive voltage divider  $R_1$  and

$R_2$ , connected between ground and the battery's positive terminal. The comparator acts as a switch which turns on the LED when the input voltage exceeds a critical value. This value is determined by the voltage on the positive input terminal. Such a circuit serves as a building block for a more complex instrument made from a number of these units, with the negative inputs connected in parallel and the positive input terminals connected to various taps on a voltage divider.

The value of current-limiting resistance  $R_L$  is found from Ohm's law by dividing the battery voltage minus the drop across the LED and comparator (about 2 volts for red and 3 volts for green LEDs) by the desired current.

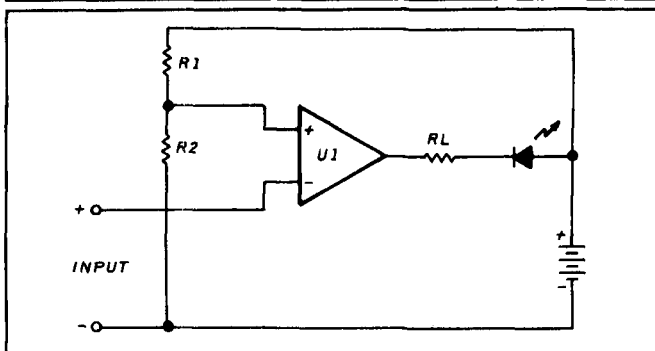
## A practical instrument

A simple instrument based on **Figure 1** could have some uses in the Amateur station. However, ICs with multiple comparator circuits are available. Chips containing four units (type 339) are the most common and are available from Radio Shack and elsewhere. My device is based on one of these chips. The circuit in **Figure 2** is a composite of two previously published diagrams. The more important portion is taken from page 87 of **Reference 3**.

The voltage divider, which establishes the reference voltages of the positive terminals, consists of four 1-k resistors in series with a 100-k trimpot. The trimpot sets the input voltage at which the first LED turns on, normally about 100 mV. It's possible to make it turn on at about 40 mV but with reduced brilliance.

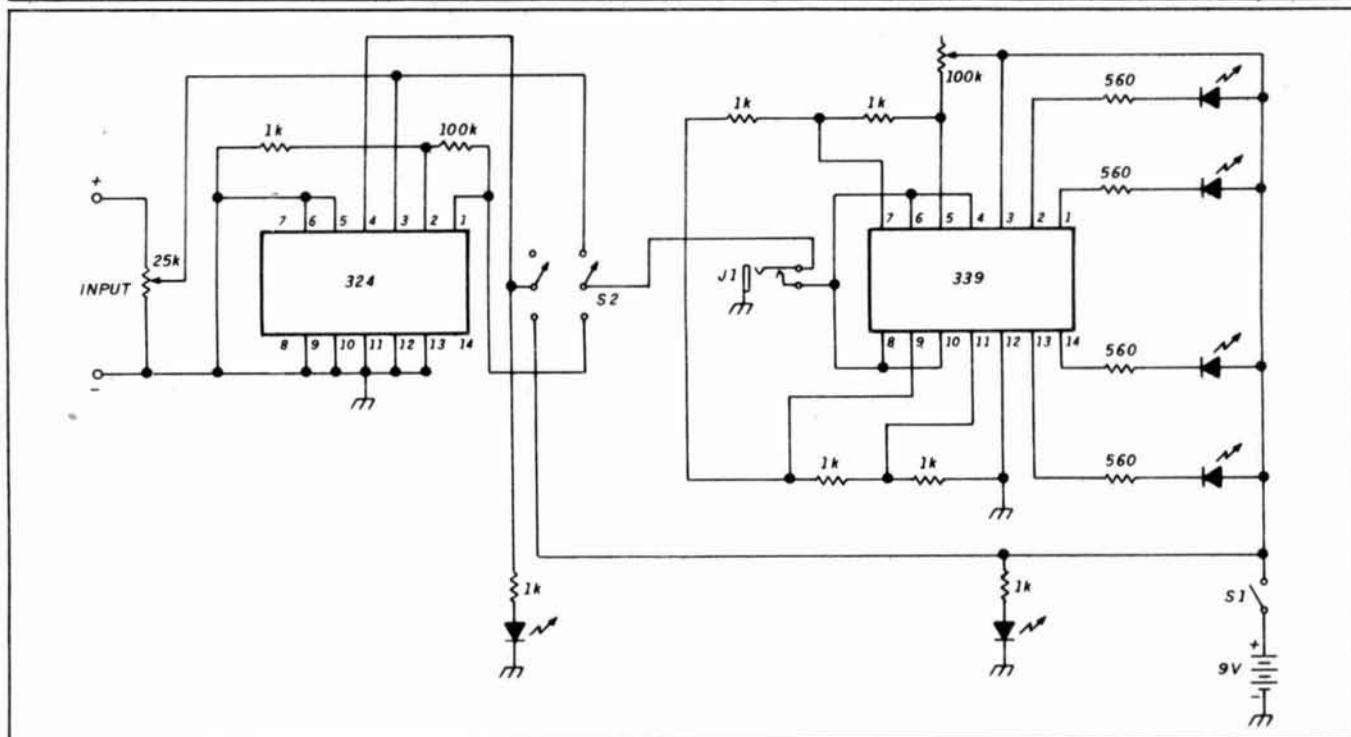
The portion of the circuit containing the 324 op amp is based on **Figure 3** of **Reference 4**, but the gain is held constant by making the feedback resistor fixed at 100 k. The gain control, consisting of a potentiometer across the input, can be used with the amplifier both in and out. I've included

FIGURE 1



**Basic circuit diagram.** When the input voltage exceeds a value determined by the voltage on the + terminal, comparator U1 acts as a switch and turns on the LED.

FIGURE 2



Circuit diagram of a practical unit. This uses the four basic units shown in Figure 1. Also included is a DC amplifier using one section of a 324 quad op amp that can be switched into the circuit.

## PARTS LIST

### Solid-state devices:

- 1 Type 339 quad comparator IC
- 1 Type 324 quad op amp IC (only one section used)
- 4 10-mA red LEDs (for display)
- 2 Miniature red LEDs (for pilot lights)

### Resistors:

- 4 560 ohm, 1/4 watt
- 7 1 k, 1/4 watt
- 1 100 k, 1/4 watt
- 1 25-k potentiometer
- 1 100-k trimpot

### Hardware:

- 1 Sardine can (small size)
- 2 Binding posts
- 1 SPST switch
- 1 DPDT switch
- 1 1/8" closed-circuit jack
- 1 Connector for 9-volt battery (salvaged from dead battery)

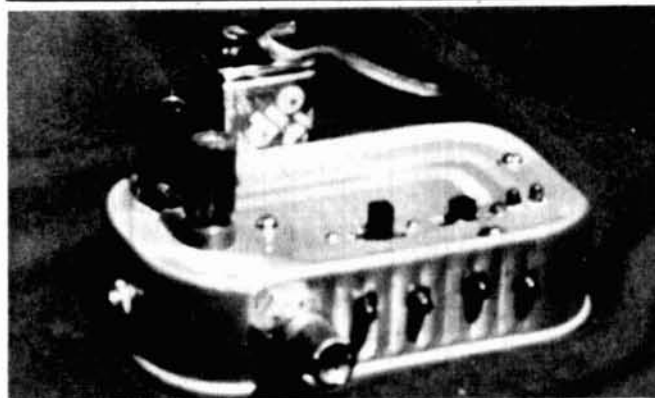
closed-circuit jack which makes it possible to use an external meter to measure amplifier input or output.

## Construction

The device is contained in a small 4 × 2-5/8 × 1-inch sardine can with a 9-volt battery clamped to the rear 4 × 1-inch surface, as shown in **Photo A**. Binding posts for the input, two slide switches, and two miniature pilot light LEDs are located on the top. The gain control and four 10-mA red LEDs for the output display are on the front. On the left you'll find the 1/8-inch closed-circuit jack connected to the op amp output.

The ICs and resistors are mounted on a 3 × 1-1/4 inch piece of perfboard (see **Photo B**). The board is supported

## PHOTO A



General view. The device is housed in a small sardine can. The four display LEDs and the gain control are on the front. Input binding posts, two switches, and two pilot-light LEDs are on the top.

from the top surface of the can by three 4-40 machine screws with 1/4-inch spacers.

I punched holes in the can with an awl, enlarging them with a drill or reamer when necessary. I mounted the LEDs by forcing them into tight fitting holes that I had carefully enlarged. I expected to use some household cement to hold them in, but I found this was unnecessary.

To mount the battery, I took two strips of sheet metal 2 inches × 1/2 inch and drilled matching pairs of clearance holes for 6-32 screws 1-3/8 inches apart. Using one of the strips as a template, I punched a matching pair of holes on the back surface of the can. Then, with one of the strips inside the can to strengthen it, I placed 1-inch bolts through

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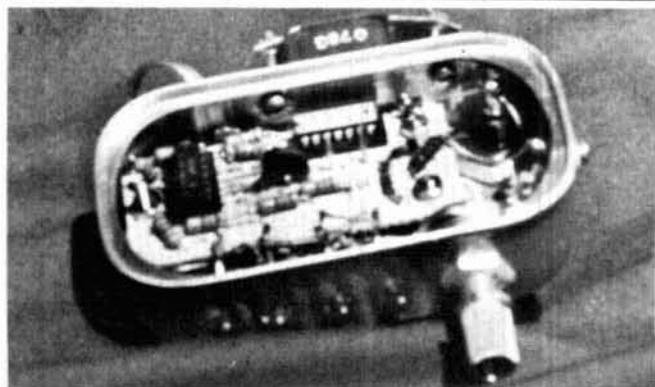
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## PHOTO B



Bottom view. The resistors and ICs are mounted on a piece of perf-board supported from the top of the can by three machine screws with spacers. The 324 op amp IC is to the left; the 339 comparator IC is at top center.


the holes facing outward. I then attached lock washers and nuts on the outside. The other strip and another pair of nuts hold the battery in place.

I wired the components on the can and perfboard separately as best I could. I provided terminals on the perfboard or leads that extended beyond it for the interconnection between the board and the can. I spliced some of these leads to those of the LEDs. Because it's easy to make connections the first time but difficult to separate them for correcting wiring errors, I checked the wiring on the perfboard very carefully with a volt-ohmmeter as I went along. This care paid off; the device worked the first time I turned it on.

## Discussion

Because decimal number systems are commonly used, you might like to have ten LEDs rather than four. You can build such a system with three type 339 chips, leaving two comparators unused. I think it's logical to arrange the voltage divider so the input-voltage increment which causes adjacent LEDs to light up is one-tenth rather than one-quarter of the voltage needed to light the last LED. This improves the resolution. Actually, ICs with ten comparators on the same chip are designed for this purpose. These chips are known as "bar graph drivers." A bar graph is a chip containing the equivalent of ten LEDs. These chips are often built into various instruments like signal strength meters. The bar graphs are more convenient in such applications, but are visible only at short distances.

There are other possible variations in the design of this device. You can arrange the taps on the voltage divider so the input-voltage increments correspond to a fixed number of decibels rather than a fixed amount of voltage. You can make a device with considerable flexibility by using a switch which connects the positive terminals of the comparators to different sets of taps on the voltage divider. Circuit diagrams for some of these alternative designs are found in Reference 3.

It's easy and fun to build this project. You can amuse visitors with demonstrations of induced emfs, antenna patterns, and a variety of physical effects. 

## REFERENCES

- Tom McMullen, W1SL, "Visual Aids — Light Emitting Diodes," *Ham Radio*, July 1989, page 56.
- Forrest M. Mims, III, *Engineer's Notebook II*, Radio Shack, 1982, page 92. Author says more details can be found in his article in *Popular Electronics*, August 1979, page 78.
- Forrest M. Mims, III, *Engineer's Notebook II*, Radio Shack, 1982, pages 87 and 90-93.
- Yardley Beers, W0JF, "A Simple DC Amplifier for Your Meter," *Ham Radio*, June 1989, page 10.

# DX Forecaster

By Garth Stonehocker, KØRYW

## SPRING FREQUENCY CHANGES

It's time for spring; winter is just about over. Are you ready for a change? How did your DXing fare this winter? Are your antennas still up? Is your operation in need of maintenance or changes? Why not get to work on these items before spring cleanup or summer yard work starts taking up your time?

Several aspects of propagation that affect DXing change during the spring and fall. The length of the day, while nearly equal to night (exactly equal this year on March 20th at 2119 UTC), changes rapidly from shorter to longer during this month and into the first weeks of April. This means that the maximum usable frequencies (MUF) for a particular path change quite rapidly. The HF commercial radio users — mainly maritime/aeronautical and broadcasters — transmitting point to point or to specific areas, need to obtain new frequency allocations from the International Telecommunication Union (ITU) during a two month interval. The annual allocation intervals of frequency usage are March to April, May to August, September to October, and November to February. Their allocations are in bands like ours: roughly 300 to 900 kHz wide at 2, 4, 6, 8, 12, 16, and 22 MHz for maritime radio, and 200 to 350 kHz wide at 6, 9, 11, 15, 18, and 21 MHz for broadcasters. Each of the maritime users have calling and working frequencies in each band. The ships use one set, the shore stations the other. They are able to use any band that's propagating to shore or ship stations in order to transact their business, so this operation mode automatically takes care of the seasonal changes of MUFs for the distance involved. Older operators have a working knowledge of propagation. To help the new operators, the shore stations send ship companies charts of frequencies to use out to concentric circles of distance at sea



from the station. Operators listen to the stations calling or working the bands to verify which will work for them. This system serves them well even when using selective calling to a specific ship. Aeronautical traffic control and the airlines, through aeronautical communication companies like ARINC or Collins, use a similar system.

The broadcasters transmit in one or two bands of allocated frequencies that should work to a target area.\* The frequency and time schedule is sent to those listeners who request it and is published in magazines like *Popular Communications*, *Monitoring Times*, or *World Radio TV Handbook*. Broadcasters are the main users of the ITU's four allocation intervals to change frequency with the season and sunspot cycle. They are restricted to this predetermined schedule, unlike the maritime/aeronautical operators who can jump from band to band until the message is passed. Those who listen to broadcast stations need to know they will be broadcasting where the published schedule indicates. Limited schedule changes (usually for QRM) are allowed by the ITU, but at the broadcasters' risk of losing their audience. You can imagine the chaos if all the broadcasters began shifting frequencies and bands at will! By using experienced propagationists, the broadcasters request frequency allocations. The ITU then uses its computers to juggle frequency assignments for the hours of the day for each season. It can be chaotic keeping signals within the bandwidth (adjacent channel interference), because propagation prediction is far from reality (by months, days, or hours) and some countries don't abide by the rules. Yet this system works pretty well, as far as propa-

gation is concerned, for the seasons and sunspot cycle.

Hams have quite a bit of freedom to shift frequencies and bands at will. We are limited only by our knowledge of propagation and our equipment (antennas on hand) to change frequency with the hour of the day, season, and sunspot cycle to work the DX or get the message through. You can see why communicators put so much significance on propagation for frequency allocation. It's important for hams too!

### Last-minute forecast

Conditions will be excellent for DX on the higher frequency bands (10 to 30 meters) the second and third full weeks of March. The MUFs will be high because of a solar flux maximum. Openings will be noticeably longer into the evening. Late evening one long hop transequatorial openings are most probable on the 5th, 14th, 23rd, and 31st, when a disturbance in the geomagnetic field and ionosphere is expected. The lower bands should provide the best DX around the 5th. Spring thunderstorms may cause local noise, but strong signals should overcome the noise — except for the actual time of the flash. Poor signals and QSB during the disturbed periods could be the big problems this month on the lower frequencies, especially on east-west paths. Spring equinox occurs on March 20th at 2119 UTC. A full moon appears on the 11th and will be at perigee on the 1st and 28th.

### Band-by-band summary

Ten, 15, and 17 meters will be open from morning to early evening almost daily in most areas of the world. Expect higher band openings to be southerly, shorter, and closer to local noon. Transequatorial propagation on these bands is likely to be toward evening during times of high solar flux and disturbed geomagnetic field conditions.

Twenty and 30 meters will be useful almost 24 hours a day. Daytime conditions will resemble those on 17 meters, but skip and signal strength may decrease during midday on days with high solar flux values. Look for good nighttime use — except after

# MARCH

GMT	PST	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN
0000	4:00	15	30	12	10	10	10	10	10
0100	5:00	12	30	15	10	10	10*	10*	10
0200	6:00	12	30	15	10	10	10	10*	10
0300	7:00	15	30	15	10	10	10	10	12
0400	8:00	17	30	17	12*	10	10	10	15
0500	9:00	20	30	17	12	12	10	10	20
0600	10:00	20	30	17*	12	15	10	10	20
0700	11:00	20	30	17	15	17	10	10	20
0800	12:00	30	30	17	15	17	12	12	20
0900	1:00	30	30	17	15	20	12	12	30
1000	2:00	30	30	17	17	20	15	15	30
1100	3:00	30	30	17	17	20	15	15	30
1200	4:00	30	17	12	17	20	15	15	30
1300	5:00	30	15	10	12	20	17	17	30
1400	6:00	20	12	10	10	20	17	17	30
1500	7:00	20	12	10	10	15	17	15	30
1600	8:00	20	12	10	10	12	17	15	30
1700	9:00	30	12	10	10	10	15	17*	30
1800	10:00	30	12	10	10	10	12	17	30
1900	11:00	30	15	10	10	10	10	12	17
2000	12:00	30	15	10	10	10	10	10	12
2100	1:00	30	17	10	10	10	10	10	12
2200	2:00	30	20	10	10	10	10	10	12
2300	3:00	17	20	12	10	10	10	10	10

MST	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN
5:00	17	30	12	10	10	10	10	10
6:00	20	30	15	10	10	10	10	12
7:00	20	30	15	10	10	10	10*	15
8:00	20	30	15	10	10	10	10	17*
9:00	20	30	17*	12	12	10	10	20
10:00	30	30	17	15	15	12	12	20
11:00	30	30	17	15	17	12	12	30
12:00	30	30	17	15	17	12	12	30
1:00	30	30	17	15	17	15	15	30
2:00	30	30	17	17	20	15	15	30
3:00	30	17	12	17	20	15	17	30
4:00	20	15	12	17	20	17	17	30
5:00	20	12	10	12	20	17	17	30
6:00	15	12	10	10	20	17	15	20
7:00	15	12	10	10	17	17	12	30
8:00	12	12	10	10	15	17	15	30
9:00	15	12	10	10	12	15	17	30
10:00	17	12	10	10	10	12	17	30
11:00	20	15	10	10	10	10	10	17
12:00	20	15	10	10	10	10	10	15
1:00	20	15	10	10	10	10	10	15
2:00	30	17	10	10	10	10	10	12
3:00	30	20	10	10	10	10	10	12
4:00	30	30	12	10	10	10	10	12

CST	ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN
6:00	17	30	12	10	10	10	10	10
7:00	20	30	15	10	10	10	10	12
8:00	20	30	15	10	10	10	10*	15
9:00	20	30	17*	12	12	10	10	17*
10:00	30	30	17	15	15	12	12	20
11:00	30	30	17	15	17	12	12	30
12:00	30	30	17	15	17	12	12	30
1:00	30	30	17	15	17	15	15	30
2:00	30	30	17	17	20	15	15	30
3:00	30	17	12	17	20	15	17	30
4:00	20	15	12	17	20	17	17	30
5:00	20	12	10	12	20	17	17	30
6:00	15	12	10	10	20	17	15	20
7:00	15	12	10	10	17	15	12	30
8:00	12	12	10	10	12	15	12	30
9:00	20	12	10	10	12*	17	15	30
10:00	20	12	10	10	10	15	17	30
11:00	20	12	10	10	10	17	15	30
12:00	30	12	10	10	10	12	17	30
1:00	30	15	10	10	10	10	12	17
2:00	30	15	10	10	10	10	10	15
3:00	30	15	10	10	10	10	10	15
4:00	30	17	10	10*	10	10	10	12
5:00	30	20	10	10	10	10	10	12
6:00	30	30	12	10	10	10	10	12

EST	ASIA FAR EAST	EUROPE	S. AFRICA	CARIBBEAN S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN
7:00	17	30	12	10	10	10	10	15
8:00	20	30	15	10	10	10	10	17*
9:00	20	30	15	10	10	10	10	20
10:00	20	30	15	10	10	10	10	20
11:00	30	30	17	12	12	12*	12	20
12:00	30	30	17	12	15	12	12	30
1:00	30	30	17*	15	17	15	15	30
2:00	30	30	17	15	17	15	15	30
3:00	30	30	17	15	20	15	15	30
4:00	30	17	15	17	20	17	17	30
5:00	15	15	10	17	20	17	17	30
6:00	15	12	10	12	20	17	17	20
7:00	12	12	10	10	20	15	15	20
8:00	15	12	10	10	17	15	12	30
9:00	17	12	10	10	12	15	12	30
10:00	20	12	10	10	12*	17	15	30
11:00	20	12	10	10	10	17	15	30
12:00	30	12	10	10	10	15	17	30
1:00	30	15	10	10	10	10	12	17
2:00	30	15	10	10	10	10	10	15
3:00	30	15	10	10	10	10	10	15
4:00	30	17	10	10*	10	10	10	12
5:00	30	20	10	10	10	10	10	12
6:00	30	30	12	10	10	10	10	12



days of very high MUF (solar flux) conditions. Usable distances on these bands should be somewhat greater than that achieved on 80 at night.

Forty, 80, and 160 meters, the nighttime DXer's bands, will open just before sunset and last until sunrise on the path of interest. Except for daytime short skip signal strengths, high solar flux values have little effect. Geomagnetic disturbances, more evident during the equinoctial periods, cause signal attenuation and fading on polar paths. Noise increases noticeably on these lower frequency bands in the coming months. *lr*

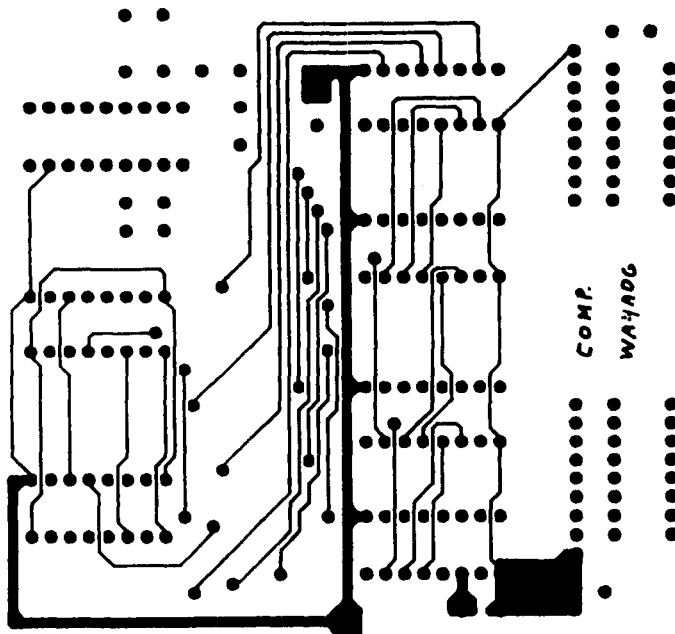
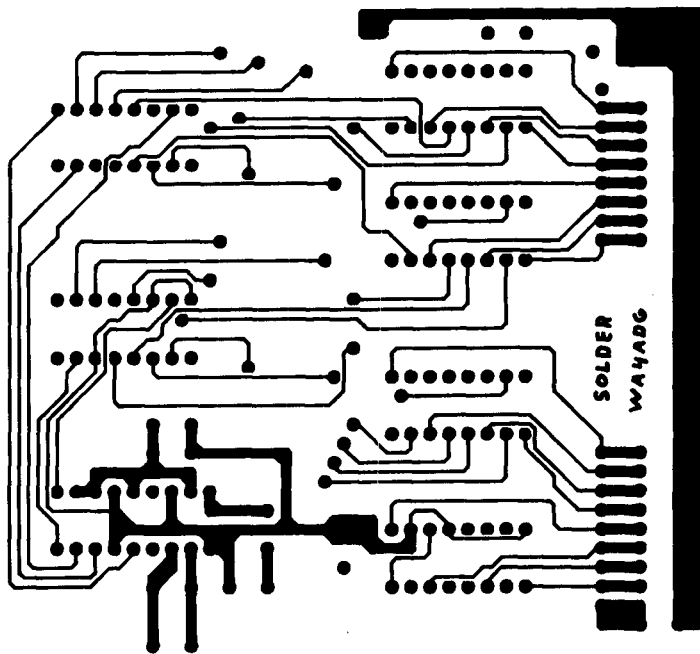
\*Using two bands at once ensures a good signal during disturbances or interference.

## Short Circuit: WA4ADG, December 1989

The pc board foil and component sides layout shown in Figure 1 on page 31 are incorrect. Here is the corrected artwork.

Please note that the pc board is double sided with all components mounted on the side designated COMP. The

author did not use a pc board with plated through holes, but rather soldered all components on both sides where applicable. Similar pc boards can be obtained from FAR Circuits, 18N640 Field Court, Dundee, Illinois 60118 for \$7.70 each plus \$1.50 shipping and handling.



  
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**450 MHz SPECTRUM ANALYZER.** Adapted from Nov 85 QST article by Al Hellrick, K2BLA. Features: Three digit LED center frequency digital readout. 12 position calibrated Scan Width, 1 kHz to 50 MHz, switchable bandwidth; Wide 5 300 kHz, Narrow 5 10 kHz. Use your low frequency scope for the display portion. Switchable 10 kHz video filter. Variable IF attenuator, LOG output calibrated in 10 db steps. For complete kit, order #450-KIT \$459.95 plus \$4.50 s/h. For assembled and tested unit, order 450-AST, \$799.95 plus \$6.50 s/h. Calif residents add 6% sales tax. Foreign orders add 15% for shipping, A & Engineering, 2521 W. LaPalma, #K, Anaheim, CA 92801. (714) 952-2114.

**IMRA** International Mission Radio Association helps missionaries. Equipment loaned. Weekend net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

**INTERESTED IN PUBLIC SERVICE?** Join your Local Radio Emergency Associated Communications Team. In Pennsylvania call (717) 938-6943 or write REACT, 1160 Old Trail Rd, Eters, PA 17319.

**RUBBER STAMPS:** 3 lines \$5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

**ELECTRON TUBES:** Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

**RECONDITIONED TEST EQUIPMENT** \$1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

## COMING EVENTS

Activities — "Places to go . . ."

**SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS:** PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC. ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

**KENTUCKY:** March 3. The 14th annual Glasgow Swapfest sponsored by the Mammoth Cave ARC, Cave City Convention Center, Cave City. Starts 8 AM. Admission \$4. Tables \$3. each. Exams will be given. Talk in on 146.34/95. For information N4HCO, 1379 Whites Chapel Road, Glasgow, KY 42141.

**MISSOURI:** March 9. 30th annual Amateur Radio Auction sponsored by the Jefferson Barracks ARC, Concordia Turner's Hall, 6432 Gravois, south St. Louis City.

**MASSACHUSETTS:** March 10. The Barnstable Radio Club's annual Hamfest, Oak Ridge School, Sandwich. Open 10 AM to buyers. 8 AM for sellers. Advance tables \$8. At the door \$10. Amateur exams given. Contact Don, WA1AIC (508) 778-5673 or Henry (508) 255-2818.

**NEW JERSEY:** March 10. Springfest '90 sponsored by the Shore Points ARC, Holy Spirit High School, Rt 9, Absecon. Doors open 9 AM. Admission \$3. Sellers spaces \$5 each. Talk in on 146.385/985 and 146.52. For information write SPARC, PO Box 142, Absecon, NJ 08201.

**NEW YORK:** March 11. WECAPFEST '90 sponsored by the Westchester Emergency communications Association. New location—Mount Pleasant Army, Valhalla. 8:30 AM to 3:30 PM. Admission \$4. Talk in on WECA repeaters 147.66/06, 222.8/224.4, 442.475/447.475. For information contact Bob Wilson, N2D2V or Sarah Wilson, N2EYX, 2 Soundview Avenue, Apt AS, White Plains, NY 10606. (914) 997-8491.

**ILLINOIS:** March 11. The 30th annual Hamfest sponsored by the Sterling-Rock Falls ARS, Sterling High School Fieldhouse, 1608—4th Avenue, Sterling. Doors open 7:30 AM. Tickets \$3/advance; \$4/door. Tables \$5 incl elec. Talk in on 146.25/146.85 W9MPE Repeater. For information, tables or tickets contact Sue Peters, Sterling Rock Falls ARS, PO box 521, Sterling, IL 61081 or call AC (815) 625-9262.

**MICHIGAN:** March 17. 29th annual Michigan Crossroads Hamfest, Marshall High School, Marshall. Sponsored by the Southern Michigan ARS and the Marshall HS Photo Electronics Club. 8 AM to 3 PM. Tickets \$3/door; \$2/advance, please SASE. For information write SMARS, PO Box 934, Battle Creek, MI 49016.

**NEW HAMPSHIRE:** Interstate Repeater Society's Hamfest, Lion's Club, Lions Avenue, Hudson, 8 AM to 4 PM. Admission \$2. Tables \$10. Talk in on 146.85, 146.55. Contact IRS, PO Box 693, Derry, NH 03038. Wheelchair accessible.

**TEXAS:** March 17-18. The Midland ARC's annual St. Patrick's Day Swapfest, Midland County Exhibit Building, East Highway 80, Midland, 10-5 Saturday and 9-2-30 Sunday. Pre-registration \$5. \$6/door. Tables \$6 each. VE tests. For information and reservations contact Midland ARC, PO Box 4401, Midland, TX 79704.

**NORTH CAROLINA:** March 17-18. Charlotte Hamfest and Computerfair, Charlotte Convention Center, 4th and College Streets, uptown Charlotte. Sat 9-5, Sun 9-2. Tickets \$5/advance; \$7/door. Children under 12 free. Tables \$12 advance only. Tickets and tables good for both days. For information and reservations write Charlotte Hamfest, PO Box 221136, Charlotte, NC 28222-1136 or call (704) 536-7373.

**FLORIDA:** March 17-18. The 20th annual North Florida Ham/Swapfest sponsored by the Playground ARC, Shrine Fairgrounds, Ft. Walton Beach. Doors open 8 AM both days. Talk in on 146.19/79 repeater. For information contact the Playground ARC, PO Box 873, Ft. Walton Beach, FL 32549.

**OHIO:** March 18. The Toledo Mobile Radio Associations's Hamfest, Lucas County Recreation Center, Key Street, Maumee, 8 AM to 5 PM. Admission \$3.50/advance; \$4/door. Talk in on 147.27 rptr, 442.85 repr. Contact Ron Morris, WB8ZIM, 28141 Glenwood Rd, Perrysburg, OH 43551. (419) 666-8063.

**CONNECTICUT:** March 18. The Insurance City Repeater Club's annual Flea Market, American School for the Deaf, West Hartford, 9 AM to 2 PM. Admission \$2. Tables \$15. Talk in on 146.28/88. Contact Chuck Motes, K2DFS, 22 Woodside Lane, Plainville, CT 06062.

**KENTUCKY:** March 24. 11th annual Hamfest sponsored by the Lincoln Trail ARC, Pritchard Community Center, Elizabethtown. Admission \$4/advance; \$5/door. For tickets, reservations, information contact Chuck Strain, AA4ZD, PO Box 342, Vine Grove, KY 40175. (502) 351-1715.

**NEW JERSEY:** March 24. Flea Market sponsored by the Chestnut Ridge Radio Club, Education Building, Saddle River Reformed Church, East Saddle River Road at Weiss Road, Upper Saddle River. Donation \$1. Tables \$10 first, \$5 each additional. Tailgating \$5. Contact Jack Meagher, W2EHD. (201) 768-8360.

**CONNECTICUT:** March 24. Annual Auction of the Radio Society of Norwich, Uncasville VFW, Uncasville. Setup 9 AM. Auction starts 10 AM. Admission is free. Wheelchair accessible. Bring equipment to be auctioned. Talk in on 146.73 repeater. For information call KA1BB at (203) 739-8016.

**OHIO:** March 25. The 12th annual Lake County Hamfest, Madison High School, Burns and Middle Ridge Roads, Madison, 8 AM to 3 PM. Admission \$4/door; \$3/advance. 6' tables \$5; 8' tables talk in on 147.21/81, 222.90/224.50. Contact LCARA Hamfest, 5777 Fenwood Ct, Mentor-on-Lake, OH 44060. (216) 257-2036.

**ILLINOIS:** March 25. Annual LAMARSFEST sponsored by the Libertyville and Mundelein ARS, Lake County Fairgrounds, Rt 120 & 45, Grayslake. Doors open 8 AM. General admission \$3/advance; \$4/door. Swap tables \$7. For information SASE to LAMARS, PO Box 751, Libertyville, IL 60048 or call Bob Dick, NY9E (708) 362-9634 after 7 PM.

**NEW JERSEY:** March 25. HAMCOMP '90, the 18th annual flea market, sponsored by the Delaware Valley Radio Association, New Jersey National Guard 112th Field Artillery Army, Eggerts Crossing Road, Lawrence Township, Trenton. Handi accessible. 8 AM to 2 PM. Admission \$3/advance; \$4/door. Talk in on 146.07. For information and space reservations write HAMCOMP'90, c/o KB2ZY, RD 1, Box 259, Stockton, NJ 08559. Please SASE.

**WEST VIRGINIA:** March 31. Hamfest and Computer Show sponsored by the Kanawha ARC and the Tri-County Ham Radio Club. 9 AM to 3 PM. Charleston Civic Center, Charleston. Admission \$5. VE exams. Talk in on 146.88/28 and 146.52. Contact Betty Palmer, WC8S, PO Box 8400, South Charleston, WV 25303. (304) 346-1348.

**NEW JERSEY:** March 31. Rain or Shine. The Cherryville Repeater Association's Flemington Hamfest, Hunterdon Central High School Field House, Flemington, 8 AM. Admission \$4/advance; \$5/door. Children under 12 and unlicensed spouses free. Table reservations and info from Marty Grozinski, NS2K, 6 Kirkbride Rd, Flemington, NJ 08822. (201) 788-4080, 5-11 PM EST.

**ILLINOIS:** March 31. Rockford Hamfest, 90.5533—11th Street, Rockford, 8 AM to 3 PM. Tickets \$3/advance; \$4/door. For information call Joe Roling, N9HEB (815) 3919-6995 or SASE to PO Box 10003, Rockford, IL 61131.

**MICHIGAN:** April 1. 32nd annual ARRL Hamfest/Swap-n-Shop sponsored by the South Eastern Michigan ARA, Grosse Pointe North High School, 707 Vernier Rd, Grosse Pointe Woods, 8 AM to 2 PM. Tickets \$2/advance; \$4/door. Tables \$8/advance; \$10/door. For information SASE to SEMARA SWAP, PO Box 646, St. Clair Shores, MI 48080-0646. (313) 323-4099.

**INDIANA:** April 7. The Columbus ARC Hamfest, Bartholomew County 4-H Fairgrounds, State Rd 11, Columbus, 8 AM to 2 PM. Talk in on 146.79—600 Hz. For information Marion Winterberg, WD9HTN, 11941 W. Sawmill Road, Columbus. IN 47201. (812) 342-4670.

**MINNESOTA:** April 7. Rochester Area Electronic and Computer Show, John Adams Junior High School, 1525 NW 31st St, Rochester. Doors open 8:30 AM. Talk in on 146.22/82. For information RARC, 2824 NW 24th St, Rochester, MN 55901.

**ONTARIO:** April 7. The 9th annual Durham Region Amateur Radio and Computer Flea Market sponsored by the South Pickering ARC, VE3SPG and North Shore ARC, VE3NSR, Pickering High School, church St, Pickering Village, Ajax, 9 AM to 2 PM. Admission \$4. For information VE2WZ (416) 839-3711; VE2MVD (416) 668-7590.

**COLORADO:** April 7. Swapfest sponsored by the Longmont ARC, Boulder County Fairgrounds, Longmont, 8 AM to 3 PM. Admission \$3. Tables \$7. For information or reservations contact Bob Dorman, W4ZEKU, 1106 Fordham St, Longmont, CO 80501. (303) 651-3613.

**MASSACHUSETTS:** April 8. The Framingham ARA is sponsoring a Flea Market and license exams for all classes. Framingham Civic League Building, 214 Concord St, Rt 126, downtown Framingham. General admission, 10 AM, \$2. Early Bird admission, 9 AM, \$5. Talk in on 147.15. For table information Jon, K1VVC, (508) 877-7166. Exam information Dick, WA1KUG, (508) 877-0568.

## OPERATING EVENTS

"Things to do . . ."

**March 17-18.** The Piscataway ARC (PARC) will operate their annual special event commemorating the Voice of America Relay station, W6OU, which operated during WW II in the Bound Brook section of Piscataway, NJ. Members will use their own call signs signing /VOA. CW- Novice portions. Phone-Lower third of General on 75, 40, 20, 15 M and Novice portion of 10M band. For certificate send #10 or 9x12 SASE with QSL to PARC, att: KB2UV, PO Box 1233, Piscataway, NJ 08854.

**THROUGHOUT 1990** the Major Armstrong Memorial Amateur Radio Club (MAMARC) will sponsor events commemorating Major Edwin Howard Armstrong's achievements in the field of radio broadcasting. The club is seeking other Amateur operators around the world who are willing to research Major Armstrong's accomplishments and become official MAMARC special events stations. Major Armstrong was a pioneer responsible for the creation of Wideband FM and the inventor of the superheterodyne receiver. If you are interested in participating and becoming an official MAMARC special event station contact Barry Group, N2HDW, MAMARC, c/o 100th Birthday Committee, PO Box 581, Alpine, NJ 07620. Please SASE.

**March 2:** Grand Island, Nebraska, ARC will operate ARS W0UCUO to celebrate the annual return of the Sand Hills crane to the Platte River refuge. 0000Z March 2 to 2400Z March 4. SSB, CW, PKT, AMTÖR and RTTY in all lower portions of General and Novice bands. For Certificate send QSL and SASE to ARC W0UCUO, PO Box 642, Grand Island, NE 68802.

**YOUTH LINK NET.** Open to all Hams under age 18. Saturdays at 2000 UTC, 28.425 MHz. For more information contact Net Control, George Manning, WB5NMH, 602 Glendale St, Burkburnett, TX 76354.

**FREE 1989-90 Florida two meter repeater directories** are currently being distributed by the Hernando County Amateur Radio Assn. of Brooksville, FL. Ask for one at any official Florida Welcome Center or SASE to Repeater Directory, Hernando County ARA, POB 1721, Brooksville, FL 34605-1721.

**AMATEUR EXAMS.** March 10, May 19, July 14, September 8, November 17. St. Mary Medical Center, 3333 No. Seminary Street, Galesburg, IL 61401. 12 Noon to 2 PM. For information contact Larry Haller, KA9PCU, 1436 Brown Avenue, Galesburg, IL 61401. (309) 342-5977.

**Monthly Ham Exams.** The MIT UHF Repeater Association and the MIT Radio Society offer monthly ham exams, all classes Novice to extra: next-to-last Wednesday of each month, (March 21) 7:30 pm, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. reservation requested a couple of days in advance, walk-ins welcome, call the shack (617) 253-3776, or Nich Allenbernd (617) 437-0320. Exam fee \$4.95. Bring copies of your current license (if any) and Certificates of Completion (if any), two forms of picture ID, and a completed form 610, available from the FCC: (617) 770-4023.

**LAUREL ARC** monthly (except December) Amateur exam sessions for all license classes. No fee is charged. Pre-registration is required. Call (301) 725-1212, Maryland Radio Center, 8576 Laureldale Drive, Laurel, MD 20707.

**AMATEUR RADIO CLASSES:** For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

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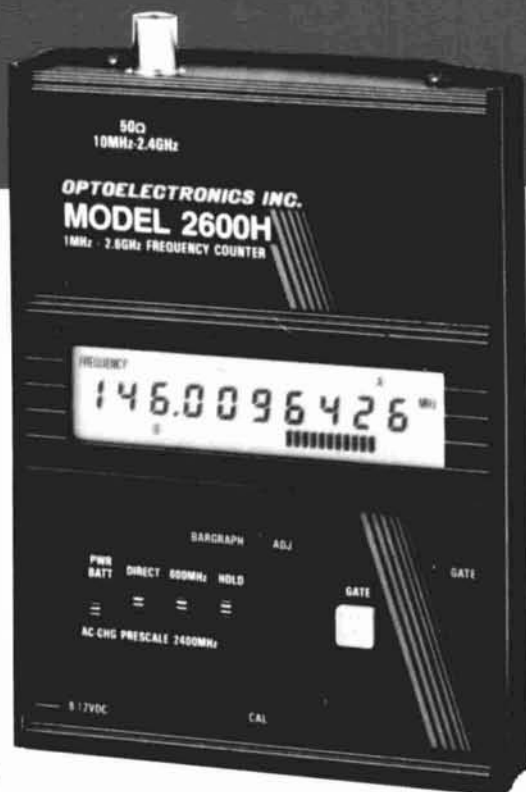
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- Squelch defeat switch.
- Used to check the frequency when CTCSS encode/decode is used.
- Easy-to-read multi-function LCD display with night light.
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- Supplied accessories: Belt hook, rubber flex antenna, PB-2 standard NiCd battery pack (for 2.5 W operation), wall charger, DC cable, dust caps.

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TH-315A/TH-415A

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- Outstanding ten memory channels
- Six TXs with 13.8 VDC input
- Wide band frequency coverage: TX from 141-163 MHz, includes 10 channels! TX on Amateur band only. (Modifiable for MARS/CAP permits required.)

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- Wide band frequency range
- Receivers from 141-163 MHz.
- Includes the weather channels!
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- 144.995 MHz (MARS/CAP dependent)
- 144.995 MHz (MARS/CAP dependent)
- battery pack (PB-2) provides 2.5 W output. Optional NiCd packs for extended operation or higher RF output available.
- CTCSS decoder optional.



- PB-1: 12 V, 800 mA NiCd pack for 5 W
- PB-2: 8.4 V, 500 mA NiCd pack (2.5 W)
- PB-3: 7.2 V, 800 mA NiCd pack (1.5 W)
- PB-4: 7.2 V, 1600 mA NiCd pack (1.5 W)
- BT-5: AA cell manganese/alkaline battery case
- PB-12: 12 V, 500 mA NiCd pack
- BC-7: rapid charger for PB-1, 2, 3, or 4
- BC-8: compact battery charger
- SMC-30: speaker microphone
- SC-12, 13, 27: soft cases
- RA-3, 5: telescoping antennas
- RA-8B: StubbyDuk antenna
- TSU-4: CTCSS decode unit
- VB-2530: 2m, 25 W amplifier (1-4 W input)
- LH-4, 5: leather cases
- BH-5: swivel mount
- MB-4: mobile bracket
- PG-2V: extra DC cable
- PG-3D: cigarette lighter cord with filter

Complete service manuals are available for all Kenwood transceivers and most accessories. Specifications, features, and prices are subject to change without notice or obligation.

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